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USER'S GUIDE TO AUXILIARY PROGRAMS FOR
THE MINTZ-ARAKAWA ATMOSPHERIC MODEL

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RAND Corporation

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A Report prepared for
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY



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Documents six computer programs used by the Rand/ARPA Climate Dynamics Project in simulating the behavior of the global atmosphere to study the complex interactions that produce world climate. The primary research tool, the Mintz-Arakawa model, runs 25 hours computing time for a 60-day simulation, generating 2 billion numbers, of which 15 million are stored in 18 arrays. The MAPGEN, Map Display, and Zonal Profile programs, documented here, post-process this output into manageable and comprehensible maps, profiles, and tables. The Difference program calculates the differences between experiments for plotting by Map Display. Two auxiliary programs are also documented, Quick Look and Disk Initializer, which greatly facilitate use of the M/A program. MAPGEN, a very large program, consists of about 4000 FORTRAN IV source cards, uses 1,250,000 bytes of core, and requires 50 minutes on one of the world's fastest computers to process the output from a 60-day simulation. The other programs are such smaller.

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PREFACE

The Rand/ARPA Climate Dynamics Project, sponsored by the Defense Advanced Research Projects Agency, uses computer simulations of the earth's climate as a means of understanding and predicting climate and its sensitivity to modification by human action, whether deliberate or inadvertent. The basic research tool is a Rand-adapted version of the Mintz-Arakawa (M/A) two-level atmospheric general circulation model developed at the University of California, Los Angeles, under National Science Foundation sponsorship (see *A Documentation of the Mintz-Arakawa Two-Level Atmospheric General Circulation Model*, Rand Report R-877-ARPA, by W. L. Gates, E. S. Batten, A. B. Kahle, and A. B. Nelson).

A characteristic of the M/A simulations is the production of large volumes of data. One 60-day simulation now produces roughly fifteen million numbers. This report documents several computer programs that handle this massive output, reducing it to more manageable and comprehensible form: three that generate maps, profiles, and tables; one that calculates and plots certain differences; and two auxiliary programs designed for more convenient and efficient use of the main program.

The author would like to thank Robert Mobley and E. S. Batten for reviewing an earlier draft of this report, and Marian Winston for her editorial help.

SUMMARY

This report is a user's guide to six computer programs employed by the Rand/ARPA Climate Dynamics Project in connection with simulations of the global atmosphere to study the highly complex interactions that produce world climate. The primary research tool of the project, the Mintz-Arakawa two-level general circulation model, is a massive program requiring 25 hours actual CPU computation time for a 60-day simulation and generating two billion numbers, of which 15 million are stored in 18 large arrays.

The MAPGEN, Map Display, and Zonal Profile programs, documented here, do postprocessing of this output, manipulating it into more manageable and comprehensible form--maps, profiles, and tables. The Difference program calculates the differences between experiments in a form that can be plotted by the Map Display program. Two auxiliary programs are documented here for completeness: Quick Look and Disk Initializer, which greatly facilitate use of the M/A program.

The MAPGEN and Map Display programs are run one after another to produce contour maps of the atmospheric variables. Together with the Zonal Profile program, they create a standard set of displays of the atmosphere over the earth's land masses and oceans. MAPGEN, a very large program, is used to obtain values and averages of a set of meteorological variables that are functions of the primary dependent variables; up to 28 variables can be obtained, some of them at both of two atmospheric levels, for each of the 3,312 nodes on the 46×72 latitude/longitude grid. These values are put on tape for input to Map Display. MAPGEN consists of about 4000 FORTRAN IV source cards, uses 1,250,000 bytes of core, and requires 50 minutes to process the output from a 60-day simulation.

Map Display uses about 150,000 bytes of core and about 20 seconds of computing time per contour plot. A contour map and a profile map of the zonal means are output for each set of values generated in MAPGEN. The standard output package consists of 50 different contour maps and the zonal mean plots for each variable, accompanied by tables of

the values, the zonal means, the meridional means, the zonal means over oceans, and the global mean. Very little computing time is required for the profile plotting routines.

Since the standard M/A output uses six-hour accumulations, and certain variables change too rapidly to be satisfactorily represented by six-hour samplings, the Zonal Profile program works from the accumulation of half-hour values for the radiation, evaporation, and heating components. This program's output package consists of up to 32 profile graphs. Zonal Profile consists of about 1500 source cards and uses about 150,000 bytes of core and 18 seconds computing time for a 60-day simulation.

The Disk Initializer, Difference, and Quick Look programs are not formal output programs, but were written to facilitate the running of the M/A model. These are much smaller programs. Disk Initializer sets up a new disk for either a new or continuation experiment. Quick Look can be used to stop the M/A simulation, read the disk, and print out the values, to enable the researcher to determine if the M/A program is operating as expected--a particularly useful function with a program that runs so many hours. The Difference program, as mentioned above, expresses the difference between two simulation experiments in a form that can be plotted by Map Display.

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I. INTRODUCTION

This report is a user's guide to six computer programs used in the Rand/ARPA Climate Dynamics Project. Under the sponsorship of the Advanced Research Projects Agency, the project performs computer simulations of the global atmosphere to study the highly complex interactions that produce world climate. Human activities may have already produced significant changes in the atmosphere, yet our knowledge of the dynamics of climate is not advanced enough to permit us to predict with confidence the results of such changes.

The primary research tool of the Climate Dynamics Project is the computer simulation of world-wide circulation patterns, using a version of the Mintz-Arakawa (M/A) two-level general circulation model originally developed at the University of California. The basic Rand adaptation of the M/A model is documented in Ref. 1, which should be consulted for more complete descriptions of the physical variables and the equations used in the simulation. There have been changes made in the model output since that report was published, and some of these are documented here.

The output now comprises 18 arrays storing a total of 15 million numbers per 60-day simulation, rather than the 10 arrays stored previously. Three new programs--MAPGEN, Map Display, and Zonal Profile--do postprocessing of the M/A output. Three auxiliary programs--Quick Look, Difference, and Disk Initializer--facilitate the use of the M/A program. An older version of MAPGEN, described in Ref. 1, is superseded by the version described below.

THE MINTZ-ARAKAWA PROGRAM

The basic numerical formulation concerns the division of the earth's atmosphere into a grid defined by 4 degrees of latitude and 5 degrees of longitude. Thus, there is a 46×72 array with 3,312 nodal points. For each node, the state variables of the atmosphere are defined at each of two levels defined by a sigma surface which is proportional to pressure. The values saved are calculated at the sigma

surfaces of one-quarter and three-quarters, where sigma equals zero at the top of the troposphere (200 mb) and 1 on the earth's surface. Selected meteorological variables (discussed more fully below) are computed for each node point every simulated half-hour. At six-hour intervals, the state variables at that time point are computed and stored in the arrays mentioned above.

The simulation of a 60-day period generates approximately 2 billion numbers, of which 15 million are stored on disk, and requires 25 hours CPU computing time on the IBM 360/91, one of the fastest computers in existence.* The MAPGEN, Map Display, and Zonal Profile programs manipulate this massive output, reducing it to manageable and comprehensible form, and the Difference program can be used to plot the comparison between two simulation experiments.

THE M/A OUTPUT PROGRAMS

Certain output routines were included in the original Mintz-Arakawa two-level general circulation model as obtained from UCLA. Using an overlay technique, the program accumulated the output arrays as it ran, and after 30 simulated days, the output arrays were written and a contour map was printed. At Rand, A. B. Nelson deleted the original output option and wrote the first versions of MAPGEN and Map Display. The present versions and the Zonal Profile program were written by the author, under the direction of E. S. Batten and A. B. Kahle. The versions described here have been in use since February 1972.

MAPGEN is used to obtain values and averages of a set of meteorological variables, such as radiation, cloudiness, rain, evaporation, albedo, etc., which are functions of the primary dependent variables. These values are then put onto tape for the Map Display program. In the present version, up to 28 different variables can be obtained, with some of these available at more than one level. The standard output package consists of 50 different maps. Map Display is used to generate contour maps from the MAPGEN output. Using IGS S-C 4060 graphics

* A modified version of the program now requires 15 hours CPU time.

routines (Ref. 2), contours of the data are drawn over a background map of the world, and the plots of zonal means are also drawn for each variable. The values themselves are also printed in tabular form, together with the zonal means, the meridional means, the zonal means over oceans, and the global mean.

Since MAPGEN samples computed variables once every six simulated hours, the normal daily variation of some of these variables, such as radiation, evaporation, and heating components, can cause a significant sampling error in the results. For studies of heat, radiation, and moisture balance, it is desirable to eliminate this error. Therefore, to obtain more accurate zonal means, the present version of the M/A program accumulates zonal arrays each half-hour for these variables and stores the values on disk. The Zonal Profile program was written to collect and plot zonal profiles of these variables.

The MAPGEN Program

MAPGEN is a very large output program. The program consists of about 4000 FORTRAN IV source cards, and uses 1,250,000 bytes of core. To generate the values for the 50 standard maps for a 30-day accumulation, MAPGEN uses up to 25 minutes of CPU time, costing about \$250 on the IBM 360/91 at UCLA.

The principal output from MAPGEN is a tape of the time-averaged values and/or snapshot values (arrays at one time point). Twenty-eight different variables can be generated.

The Map Display Program

The Map Display program uses approximately 150,000 bytes of core and about 20 seconds of CPU time per contour plot on the 360/91. The printing and profile plots use very little CPU time.

For each set of values generated in MAPGEN, a contour map and a profile plot of the zonal means are generated in Map Display. The array values are also printed, together with the zonal means, the zonal means over oceans, the global means, the meridional means, and the map title. The contour map, identifying the local high and low values of the array, is drawn on a base map outlining the continents.

The values of the contours drawn are determined by specifying the contour interval and the value of one contour to be drawn as a dashed line. The other isoline values are positive and negative multiples of the isoline interval from the dashed-line value. Alternatively, the user may input up to 15 arbitrary isoline values, including his choice of the dashed-line value. See Fig. 1, p. 29, for a sample contour map.

The contour map is usually a rectangular projection, but polar projections can also be plotted if desired. The polar projections can be either stereographic or equidistant projections, and of course can be centered on either the North or the South Pole.

For the profile plot of the zonal means, the program finds the largest value of the zonal means and uses that as the scale factor for the graph. While this method of scaling has advantages, it makes comparison of these graphs difficult. (See Fig. 2 on p. 30 for a sample zonal means graph.)

Map Display output options enable the user to select the printout, contour map, and/or zonal means graph.

The Zonal Profile Program

The Zonal Profile Program uses approximately 150,000 bytes of core and requires nine seconds of CPU time to generate 32 profile graphs from a simulated 30-day period. The program consists of about 1500 FORTRAN IV source cards. A sample profile graph is given in Fig. 3 on p. 34.

From the zonal means saved during the integration of the M/A program, the Zonal Profile Program generates up to 32 different profiles, including profiles of radiation components, evaporation, cloudiness, and energy balance. The zonal variables are averaged over a given time period from values calculated each half-hour, and then are output in both printed and graphic forms.

The Smaller Programs

In addition to the three formal output programs, three smaller programs are necessary to use the M/A program effectively. These are called the Quick Look Program, the Difference Program, and the Disk Initializer Program.

The Quick Look Program reads the M/A disk output and prints out the data. At checkpoints throughout the M/A simulation, the M/A program may be stopped and the data on disk inspected, via Quick Look, to determine if the program is behaving as expected. Both the state variables and the accumulated zonal means are printed by the program.

The Difference program is used to calculate the differences between two experiments. Two data tapes generated by MAPGEN are used to form a new tape to be used by the Map Display program to form maps of the differences.

The Disk Initializer program is used exclusively by the programmer in conjunction with the running of the M/A program. This program will set up a new disk, either for the continuation of an experiment or for the beginning of a new experiment.

ORGANIZATION OF THIS REPORT

The next section describes the new format of the M/A disk output. This is followed by user's guides for the six programs.

Four appendices are given at the end of the program. Appendix A is a listing of the standard input package for MAPGEN and Map Display. Appendix B is a printout of the data on a simple variable (degrees Centigrade) from the Map Display program. Appendix C gives the correspondence between the new and old numbers for the MAPGEN map-types, as documented here and as documented previously in Ref. 1. And Appendix D presents tabular detail concerning program variables, symbols, and arrays.

II. M/A DISK OUTPUT

To understand any of the M/A output programs, the user must first understand what the M/A program has written onto disk during its simulation.

The M/A simulation program forms two data sets for a time history of the run. The larger of the data sets consists of large 46×72 grid-point arrays, with the smaller consisting of a number of 46×1 zonal arrays.

THE LARGE ARRAY DATA SET

At the beginning of the large array data set, two arrays that never change throughout the simulation are given. These are TOPOG, the surface topography indicator, and ALBEDO, the surface albedo, which appears as ALS in the COMP3 subroutine.

Table 1

SYMBOLS USED IN THE TOPOGRAPHY ARRAY

1. If $\text{TOPOG} > 1.0$, then the grid point is ocean and the value is the ocean temperature in degrees Kelvin.
2. If $\text{TOPOG} < 1.0$ and $> -10^6$, then the grid point is land and the value is the negative of the altitude in meters multiplied by the gravitational constant, GRAV (9.81).
3. If $\text{TOPOG} < -1.0 \times 10^6$, then the grid point is land ice and the value is -1.0×10^6 minus the altitude in meters multiplied by the gravitational constant.
4. If $\text{TOPOG} = -1.0 \times 10^6$, then the grid point is sea ice.

Once every six hours of simulated time, the program writes data onto the disk in the two data sets. The large array data set can be divided into four sections: (1) time record, (2) the pre-COMP3 values

(explained below), (3) the state variables, and (4) the precipitation arrays. Table 2 gives the arrangement on disk for each time point for this data set. The other data sets consist of zonal arrays.

Table 2
FORMAT FOR EACH COMPLETE SET OF TIME-DEPENDENT DATA

	TAU,C(800)
Pre-COMP3 Arrays	$\left\{ \begin{array}{l} T(46,72,2) \\ Q3(46,72) \\ GW(46,72) \\ GT(46,72) \end{array} \right.$
State Variable Arrays	$\left\{ \begin{array}{l} P(46,72) \\ U(46,72,2) \\ V(46,72,2) \\ T(46,72,2) \\ Q^3(46,72) \\ GW(46,72) \\ GT(46,72) \end{array} \right.$
Precipitation Arrays	$\left\{ \begin{array}{l} ACPPLS(46,72) \\ ACPPC1(46,72) \\ ACPPC3(46,72) \end{array} \right.$

The Time Record (TAU) and Constant Array

The first record at each time point contains the reference time, TAU, in hours, and an array, C, of 800 constants used in the M/A simulation and the output programs.

For historical reasons, the starting point of the Rand-M/A simulations is not TAU = 0, but TAU = 8160, or day 340. The time of year is determined by a variable (SDEDY) within the C-array. For experiments at RAND, day 340 corresponds to December 1.

Pre-COMP3 Arrays

Rather than save on disk all the variables which may be needed, the values of some state variables are saved before they are adjusted by subroutine COMP3, thereby allowing the variables defined in COMP3 to be obtained by a postprocessing pass. The pre-COMP3 variables saved are:

Table 3

PRE-COMP3 ARRAYS

T	Temperature at tropospheric levels 1 and 3 in degrees Kelvin
Q3	Mixing ratio at level 3
GT	Ground temperature in degrees Kelvin
GW	Ground wetness fraction

State Variables

The state variables after the complete integration step are stored on the disk for each output time. The arrays are dimensioned 46×72 , representing the latitude/longitude grid points. The state variables include:

Table 4

STATE VARIABLES

P	Surface pressure in millibars, minus the troposphere pressure (200 mb)
U	Horizontal zonal wind at levels 1 and 3 in meters/sec
V	Meridional wind at levels 1 and 3 in meters/sec
T	Temperature at tropospheric levels 1 and 3 in degrees Kelvin
Q3	Mixing ratio at level 3
GW	Ground wetness fraction
GT	Ground temperature in degrees Kelvin

For further explanation of these symbols and arrays, see Ref. 1.

Precipitation Arrays

Since precipitation rates can be highly variable and thus the true total precipitation be lost by sampling only every six hours, the M/A program accumulates the precipitation data every half-hour. This information is written onto disk in three arrays for each six hours of simulation.

Table 5

PRECIPITATION ARRAYS

1. ACPPLS, representing $PREC \times P$, where PREC is level 3 moisture change due to large-scale precipitation, and P is surface pressure. To obtain units of mm/day, multiply by $200/GRAV$, where $GRAV = 9.81 \text{ m/sec}^2$.
2. ACPPC1, representing $(PC1 + C1) \times P$, where PC1 is level 1 temperature change due to penetrating convection, and C1 is level 1 temperature change due to mid-level convective latent heating. To obtain units of mm/day, multiply by $200/(GRAV \times CLH)$ where $GRAV = 9.81$ and $CLH = .24/580$.
3. ACPPC3, representing $(PC3 + C3) \times P$, the equivalent values for level 3. To obtain units of mm/day, multiply by $200/(GRAV \times CLH)$ where $GRAV = 9.81$ and $CLH = .24/580$.

ACCUMULATED ZONAL MEANS OUTPUT

At the same time that the precipitation data set is written, the M/A program writes into another data set a set of twenty-four or twenty-five accumulated zonal arrays, depending on the version of the M/A program used. The zonal arrays are accumulated every half-hour and are written onto the disk every six hours. At each time point, TAU, the time in hours, is written in one record, followed by the twenty-four or -five records, each containing a 46-word zonal mean array.

To insure that the zonal arrays are stored onto disk, the M/A model writes TAU and the zonal arrays followed by a dummy record at each time point. Then, before the next write, a backspace over the dummy record is performed. But, at the end of the data set, the dummy record remains. This record can be recognized by the fact that the first value is much smaller than TAU, approximately 10^{-82} . When two of these data sets are concatenated, TAU must be tested so that the dummy record can be skipped.

As the disk is written every six hours, and the computational subroutine COMP3 which computes these values is executed every half-hour, each array on disk is the sum of the arrays for 12 time points. Therefore, the set of data arrays written at each time point is the accumulation from the previous six hours.

The array values are described below in the order in which they appear on the disk. A short mnemonic and a description is given for each variable. If a formula is given, the names used in the formula are described below or in the FORTRAN dictionary in Ref. 1. If a formula is not given, the mnemonic itself is a variable name described in that reference.

The following variable names are used in the formulas:

L = latent heat of condensation = 580 cal/g

CP = dry air specific heat at constant temperature = 0.24
cal/g/deg

g = gravitational constant = 9.81 m/sec²

p = surface pressure values, which change with time

The Zonal Array Values in disk order are given in Table 6.

Table 6

ZONAL ARRAY VALUES IN DISK ORDER

1. CL1--the deep convective cloudiness indicator; see the Map 14 description in the MAPGEN User's Guide.
2. CL2--the large-scale convective cloudiness indicator; see the Map 14 description in the MAPGEN User's Guide.
3. CL3--the low-level convective cloudiness indicator; see the Map 14 description in the MAPGEN User's Guide.
4. CL--the total cloudiness indicator; see the Map 14 description in the MAPGEN User's Guide.
5. E4--the surface evaporation rate.
6. F4--the surface sensible heat flux.
7. AS1--the insolation absorbed by the upper layer.
8. AS3--the insolation absorbed by the lower layer.
9. R0--the net upward long-wave radiation flux at tropopause.
10. R2--the net upward long-wave radiation flux at level 2.
11. R4--the net upward long-wave radiation flux at the surface.

12. S4--the total flux of short-wave radiation absorbed by the ground.
13. RETOT--the total solar radiation reflected from the Earth-atmosphere system. The variable RETOT is calculated in the following way:

$$\text{RETOT} = \text{SS} * \left(\frac{\text{CL} * \text{ALAC} * (1 - \text{ALS})}{1 - \text{ALAC} * \text{ALS}} + \frac{(1 - \text{CL}) * \text{ALAO} * (1 - \text{ALS})}{1 - \text{ALAO} * \text{ALS}} \right) + \text{FS4C} + \left(\frac{\text{S4} * \text{ALS}}{1 - \text{ALS}} - \frac{\text{TEMS} * \text{CL}}{1 - \text{TEMP} * \text{ALS}} \right)$$

where TEMS and TEMP are one of four sets of values depending on the cloudiness values CL1, CL2, and CL3, as follows:

1. If CL1, CL2, and CL3 ≤ 0.0, TEMS = TEMP = 0.0
2. If CL3 > 0.0 and CL1, CL2 ≤ 0.0, then:

$$\begin{aligned} \text{TEMS} &= \text{SA} * (1 - \text{ALC3}) * (1 - .271 * [(\text{EFV0} - \text{EFV3})/\text{COSZ} \\ &\quad + 1.66 * (\text{EFVC3} + \text{EFV3})]^{.303}) \\ \text{TEMP} &= \text{ALC3} \end{aligned}$$

3. If CL2 > 0 and CL1 ≤ 0, then:

$$\begin{aligned} \text{TEMS} &= \text{SA} * (1 - \text{ALC2}) * (1 - .271 * [(\text{EFV0} - \text{EFV2})/\text{COSZ} \\ &\quad + 1.66 * \text{EFVC2} * \text{COT} + \text{EFV3}]^{.303}) \\ \text{TEMP} &= \text{ALC2} \end{aligned}$$

where COT = Min(1.0, (RH3 - 0.9) * 10.0)

4. If CL1 > 0, then:

$$\begin{aligned} \text{TEMS} &= \text{SA} * (1 - \text{ALC1}) * (1 - .271 * [(\text{EFV0} - \text{EFV1})/\text{COSZ} \\ &\quad + 1.66 * (\text{EFVC1} + \text{EFV3})]^{.303}) \\ \text{TEMP} &= \text{ALC1}. \end{aligned}$$

14. SCOSZ--the total solar radiation at the top of the atmosphere.
15. STRA = SA - ASOT--the short-wave absorption above the troposphere.
16. PPTOT = [PREC + (CP/L) * (C1 + C3 + PC1 + PC3)] (P/2g) * 4800--the total precipitation.
17. HL1 = (C1 + PC1) * 48--latent heating at sigma level 1/4.
18. HL3 = (C3 + PC3 + (CP/L) * (PREC) * 48--latent heating at sigma level 3/4.
19. HSW1 = AS1 * (2g/P) / (CP/10)--the short-wave heating at sigma level 1/4.
20. HSW3 = AS3 * (2g/P) / (CP/10)--the short-wave heating at sigma level 3/4.
21. HLW1 = (R2 - R0) * (2g/P) / (CP/10)--the long-wave heating at sigma level 1/4.
22. HLW3 = (R4 - R2) * (2g/P) / (CP/10)--the long-wave heating at sigma level 3/4.
23. HF4 = F4 * (2g/P) / (CP/10)--the sensible heat from the Earth.
24. CICE = the heat rising through ice; see the Map 23 description in the MAPGEN User's Guide.
25. HDIF--the smoothed heating terms as computed in COMP3. H1 and H3 are the temperature changes at sigma surfaces 1/4 and 3/4 respectively. These values are smoothed before being added to the temperature, by area smoothing $(H1 + H3)/2$ and adding $(H1-H3)/2$ for sigma level 1/4 and subtracting $(H1-H3)/2$ for sigma level 3/4 temperature changes. HDIF is the smoothed value of $(H1 + H3)/2$.

Note: This zonal array was not put onto disk in the version of the M/A program used in experiments 10-13. The error in calculating total heating with this term omitted is not large; however, the array has been added for the sake of accuracy.

The values saved on disk differ by a constant from the six-hour average quantities listed above. Each of these arrays has to be multiplied by the constant given in Table 7 in order to obtain desired units.

as shown. The number 12 appears in the constants because COMP3 is executed 12 times in each six-hour period, and 72 is the number of longitude points accumulated at each latitude. The radiation unit of lang-leys is abbreviated as ly.

Table 7

CONVERSION FACTORS FOR ZONAL ARRAYS ON DISK

Variable × Const. = Units			Variable × Const. = Units		
CL1	$\frac{1}{12 \cdot 72}$	fraction	RETOT	$\frac{1}{12 \cdot 72}$	ly/day
CL2	$\frac{1}{12 \cdot 72}$	fraction	SCOSZ	$\frac{1}{12 \cdot 72}$	ly/day
CL3	$\frac{1}{12 \cdot 72}$	fraction	STRA	$\frac{1}{12 \cdot 72}$	ly/day
CL	$\frac{1}{12 \cdot 72}$	fraction	PPTOT	$\frac{100}{36 \cdot g}$	mm/day
E4	1000	mm/day	HL1	$\frac{48}{12 \cdot 72}$	deg C/day
F4	$\frac{1}{12 \cdot 72}$	ly/day	HL3	$\frac{48}{12 \cdot 72}$	deg C/day
AS1	$\frac{1}{12 \cdot 72}$	ly/day	HSW1	$\frac{2 \cdot g}{12 \cdot 72 \cdot 10 \cdot CP}$	deg C/day
AS3	$\frac{1}{12 \cdot 72}$	ly/day	HSW3	$\frac{2 \cdot g}{12 \cdot 72 \cdot 10 \cdot CP}$	deg C/day
R0	$\frac{1}{12 \cdot 72}$	ly/day	HLW1	$\frac{2 \cdot g}{12 \cdot 72 \cdot 10 \cdot CP}$	deg C/day
R2	$\frac{1}{12 \cdot 72}$	ly/day	HLW3	$\frac{2 \cdot g}{12 \cdot 72 \cdot 10 \cdot CP}$	deg C/day
R4	$\frac{1}{12 \cdot 72}$	ly/day	HF4	$\frac{2 \cdot g}{12 \cdot 72 \cdot 10 \cdot CP}$	deg C/day
S4	$\frac{1}{12 \cdot 72}$	ly/day	CICE	$\frac{1}{12 \cdot 72}$	ly/day
			HDIF	$\frac{48}{12 \cdot 72}$	deg C/day

III. USER'S GUIDE FOR MAPGEN

The MAPGEN program reads the disk written during the M/A simulation program, combines variables stored on the disk into meteorologically meaningful parameters, and prepares a tape for the Map Display program which draws contour maps and graphs of the zonal averages. The standard output (see description below) consists of maps and zonal average graphs of 28 variables. Many of the variables can be mapped at more than one level. While the 28 variables are commonly used, new maps may be defined and included in MAPGEN, or some of the 28 may be excluded.

In order to recover the meteorological variables calculated during the integration of the M/A model within subroutine COMP3, MAPGEN uses the pre-COMP3 arrays on disk plus the subroutine COMP3 to recalculate these values. The version of COMP3 used for MAPGEN is different from the M/A COMP3, but the actual calculations are the same for both programs. Many experiments involve a change to COMP3 in the M/A program, and these changes must also be made to the MAPGEN version of COMP3 in order to obtain correct values. For this reason, as a general rule, COMP3 should *always* be compiled when MAPGEN is run. This listing can then be referred to if questions arise about the values calculated in MAPGEN.

MAPGEN can sample data from the history disk at specified single time points or collect and time-average data over specified time periods. In calculating the time averages, the starting and ending data points are given half the weight of each interior time point. If these times were, for example, 370.0 to 400.0--a thirty-day average--the values at each end point would be multiplied by one-half and then added to the values for each six hours from 370.25 to 399.75 days. At the end of the accumulations, the numbers are averaged by dividing the total by 120--not by 121, as would be the case if the beginning and ending days were counted at full value. Although a thirty-day average is most commonly requested, the averaging period is arbitrary and, like the other options, is controlled by the input cards.

INPUT FORMATS

The first card of the MAPGEN run is the header card (read only once for each run).

HEADER CARD FORMAT

Column	Format	Meaning
1	I1	Describes new disk format; leave blank
2-77	19A4	A title printed at the beginning of MAPGEN output. In Map Display, this title is printed on each page and frame of output.

Following the header come the sets of map cards. The first card of each set inputs, among other things, the start and end times for the time averaging. In MAPGEN, a maximum of 40 maps may be called for with one set of data; however, in each run, as many sets may be input as needed. Each set, if it contains less than 40 map cards, is terminated by a blank card, and the last set is terminated by two blank cards. (If exactly 40 map cards are input, the sets should not be separated by a blank card.)

If a run consists of more than one set of data, the user should keep in mind that the computational subroutine, COMP3, uses most of the CPU time. This is true even though all of the variables computed by COMP3 at a time point are found in one pass through the subroutine. The 13 variables that use COMP3 should therefore be collected into one set of data, and those that do not, into another. The map numbers of the 15 variables that do *not* use COMP3 are 1-8, 10-13, and 15-17. The format of the first card of each set is given in Table 8, and the format for the map cards, in Table 9.

The data cards for MAPGEN can also be used for the Map Display program, which minimizes input preparation for the two programs. However, for Map Display, a blank card must always separate the sets of input cards.

Table 8

FORMAT OF FIRST CARD OF EACH SET FOR MAPGEN INPUT

Column	Format	Meaning
1-10	F10.0	Time to start in days, e.g., 370.0
11-20	F10.0	Time to end in days, e.g., 400.0 <i>Note:</i> The data for a single time point can be obtained by setting the start and end times to be the same.
21-30	F10.0	Projection type: 0.0 = rectangular 1.0 = north stereographic -1.0 = south stereo 2.0 = north equidistant -2.0 = south equidistant.
31-40	F10.0	If nonzero, cards of the zonal mean values are punched in MAPGEN. The value in these columns is truncated to an integer value and punched on the cards as the experiment number. See Punched Output described on page 23.

Table 9
FORMAT OF MAP CARDS FOR MAPGEN AND MAP DISPLAY INPUT

Column	Format	Meaning
1-2	I2	The map number, between 1 and 28, right adjusted.
3-7	F5.0	SURF, the sigma surface, e.g., 0.25, 0.75, 1.0, or for some maps the pressure, e.g., 400.0 mb, 800.0 mb. For convenience, this value will be called SURF in later discussions. The sigma surface is 1.0 for the surface and 0.0 for the top of the troposphere.
8-12	F5.0	The isoline interval. Isoline values are calculated using positive and negative multiples of this value, starting from the dashed-line isoline value.
13-17	F5.0	Value of the isoline to be dashed.
18-22	F5.0	Not used.
23-27	F5.0	Number of copies of the array to be printed at this time, normally 1.0. If 0.0, the values are not printed.
28-32	F5.0	Number of specific isoline values to be read (≤ 15). If these columns are zero or blank, the isoline intervals described by 8-12 and 13-17 are used. Otherwise, one additional card is read for the map description. It contains the map number in columns 1-2 as usual, followed by as many as 15 specific values of isolines to be contoured (each in F5.0 format). <i>This extra card does not count toward the limit of 40 map cards per set.</i> Note that the dash line value has to be input among the values if it is to be drawn.
33-37	F5.0	If <i>not</i> zero, then zonal means are <i>not</i> to be graphed in the Map Display program.
38-42	F5.0	If <i>not</i> zero, the contour map is <i>not</i> graphed in the Map Display program.

Only the first seven columns of the map cards are used by MAPGEN. The map number determines the variable to be used, and the value of SURF specifies the level at which the variable is desired.

STANDARD OUTPUT MAP DESCRIPTIONS

A standard set of variables is plotted for each simulation. This standard output package consists of two sets of data, the first not using COMP3 and the second using the subroutine. The card input for this package is listed in Appendix A. Some of the 28 different variables are available at more than one level. The value of SURF (meaning surface or pressure) usually denotes the sigma surface level, but it is sometimes a pressure level or, in some cases, simply a flag to distinguish different maps.

Table 10 gives the map numbers and titles, showing the units of the variables. The values of SURF are also given for the standard input package--SURF usually indicates the tropospheric level, expressed either as a sigma level or as a pressure in millibars, as described above. Some of the variables are identified by different map numbers in Chap. IV of Ref. 1, the Mintz-Arakawa documentation. The variables have since been renumbered. See Appendix C for the correspondence of map numbers. Variables not discussed in Ref. 1 are described in Table 11, below.

MAPGEN OUTPUT

The printed output of MAPGEN is very limited. The title card is printed, then the input cards of each data set are printed out, with the end of each set followed by a row of zeros. After the data set has been printed, the M/A disk data sets are read in. For each time record read, the time point in hours and days is written out. A new page is started when the first time point to be included is reached. When all of the values have been averaged, the information is written onto tape and a description of each map is written out, consisting of the first and last times of the accumulation, the number of accumulations, the map number, the SURF value, and the map title.

Table 10

MAP TITLES FOR MAPGEN OUTPUT

Map No.	SURF for Standard Output	Uses COMP3	Title
1	1.0	No	Topography (ocean temperature, deg C)
	3.0	No	Topography (surface elevation, hectofeet)
2	1.0	No	Sea Level Pressure Smoothed (mb - 1000)
3	0.25, 0.75, 1.0	No	Pressure at Sigma Surface (mb)
4	0.25, 0.75, 400, 800	No	Geopotential Height (hectometers)
5	0.25, 0.75, 400, 800	No	East-West (u) Wind Component (m/sec)
6	0.25, 0.75, 400, 800	No	North-South (v) Wind Component (m/sec)
7	0.5	No	Sigma Vertical Velocity (mb/hr)
8	1.0	No	Ground Temperature (deg C)
9	1.0	Yes	Surface Air Temperature (deg C)
10	0.25, 0.75, 400, 800	No	Temperature (deg C)
11	1.0	No	Ground Wetness (scaled zero to ten)
12	0.75	No	Relative Humidity (percent)
13	1.0	No	Precipitable Water (cm)
	0.25	Yes	CL1 - Deep Convective Cloudiness
14	0.75	Yes	CL2 - Large-Scale Cloudiness
	1.0	Yes	CL3 - Low-Level Convective Cloudiness
	2.0	Yes	CL - Total Cloudiness
15	1.0	No	Large-Scale Precipitation (mm/day)
16	1.0	No	Convective Precipitation (mm/day)
17	1.0	No	Total Precipitation (mm/day)
18	1.0	Yes	Evaporation (mm/day)
19	1.0	Yes	Surface Heating by Evaporation (100 ly/day)
20	1.0	Yes	Sensible Heat Flux (10 ly/day)
21	1.0	Yes	Surface Insolation Absorption (100 ly/day)
22	1.0	Yes	Surface Long-Wave Heating (100 ly/day)
23	1.0	Yes	Surface Heat Balance (100 ly/day)
24	0.25	Yes	Latent Heating in Layers (sigma = 0 to .5) (deg/day)
	0.75	Yes	Latent Heating in Layers (sigma = .5 -1) (deg/day)
25	0.25, 0.75	Yes	Absorption of Insolation in Layers (deg C/day)
26	0.25, 0.75	Yes	Long-Wave Heating in Layers (deg C/day)
27	0.25, 0.75	Yes	Total Heating (deg C/day)
28	1.0	Yes	Net Albedo

Table 11

VARIABLES NOT COVERED IN GATES, ET AL., BY MAP NUMBER

Map	Variable	Formula or Calculation Method
3	Pressure	$PTROP + SURF \cdot 3$ <p>where PTROP = tropopause pressure = 200mh, SURF = sigma surface, P = surface pressure parameter</p>
7	Sigma Vertical Velocity Meridional Mass Flux	Defined in Ref. 1, p. 170. From these values, the zonal mean values of the meridional mass flux are calculated; these are printed and graphed in the Map Display program. Calculated at sigma surface of 1/2. SURF is not used. See p. 28 for formula.
14	Cloudiness CL1 Deep convection CL2 Large-scale CL3 Low-level CL Total	<p>Collected when SURF \leq 0.5 Collected when SURF between 0.5 and 1.0 Collected when SURF over 1.0</p> <p>Calculated in COMP3 by:</p> <p><u>Deep Convective Cloudiness (CL1)</u> if both C1 and PC1 70.0, CL1 = 0.0, i.e., if there is no positive temperature change in level 1 due to convective latent heating (C1) or to penetrating convection (PC1); otherwise, $CL1 = \text{Max} [0.0, \text{Min}(RH3 \cdot 1.25) - .25, 1.0]$ where RH3 is the level 3 relative humidity.</p> <p><u>Large-Scale Cloudiness (CL2)</u> CL2 is either 0.0 or 1.0. CL2 = 1.0 if RH3 0.9, otherwise CL2 = 0.0.</p> <p><u>Low-Level Convective Cloudiness (CL3)</u> CL3 is 0.0, except if the stability parameter for low-level convection (EX) is greater than zero and the level 1 temperature change due to penetrating convection (PC1) is equal to 0.0, in which case: $CL3 = \text{Max}[0.0, \text{Min}(1.25 \cdot RH3) - .25, 1.0]$</p> <p><u>Total Cloudiness (CL)</u> $CL = \text{Max} (CL1, CL2, CL3)$</p> <p>For these maps, SURF is not printed on the map frames.</p>
15	Large-scale Precipitation	<p>Computed from the accumulated half-hour values of PREC \cdot P (precipitation at each grid point) that are saved at each output time. It is given by the expression:</p> $\frac{48}{2g} \cdot \frac{10^2}{\rho_w} \left(\frac{1}{12} \sum_{i=1}^{12} (PREC \cdot P)_i \right)$ <p>where $\rho_w = 1 \text{ g/cm}^3$, i represents the ith half-hour value, PREC is the level 3 moisture change due to large-scale condensation, and P is the surface pressure parameter. SURF is not used.</p>
16	Convective Precipitation	<p>Produced from the accumulated half-hour values of (PC1 + C1) \cdot P and (PC3 + C3) \cdot P that are saved at each output time. It is given by the expression:</p> $\frac{48}{2g} \cdot \frac{10^2}{\rho_w} \cdot \frac{C}{L} \left[\frac{1}{2} \left\{ \sum_{i=1}^{12} [(PC1 + C1) \cdot P]_i + \sum_{i=1}^{12} [(PC3 + C3) \cdot P]_i \right\} \right]$ <p>SURF is not used.</p>

Table 11--continued

Map	Variable	Formula or Calculation Method
19	Surface Heating by Evaporation	Computed from the expression: $-L \cdot E4 \cdot 864.0$ where L = latent heat (580.0) and E4 = surface evaporation rate. SURF is not used.
22	Surface Long-wave Heating	The negative of this variable is described on p. 212 of Ref. 1. The expression is: $-R4/100$ where R4 is the net upward long-wave radiation at the Earth's surface. SURF is not used.
23	Surface Heat Balance	The values for this map equal $\text{Map 21} + \text{Map 22} - (\text{Map 20} \cdot 10^{-1}) + \text{Map 19} + \text{CICE} \cdot 10^{-1}$ where CICE is 0 for land or ice-free ocean. When this grid point is sea ice, $\text{CICE} = \text{TEM} \cdot (\text{TICE} - \text{TG})$ where TEM = CTID/HICE, the thermal conductivity of ice (=432) over the effective ice thickness (=300); TICE = melting point of ice (=273.1); and TG is the ground temperature. SURF is not used.
24	Latent Heating in Layers	The map for the sigma level 0 to one-half is described by: $(\text{C1} + \text{PC1}) \cdot 48$ where C1 and PC1 are level 1 temperature change due to mid-level convective latent heating and to penetrating convection, respectively. The number 48 puts the values in the units degs C/day. The map for the sigma level one-half to 1.0 is described by: $(\text{C3} + \text{PC3} + \text{CLH} \cdot \text{PREC}) \cdot 48$ where C3 and PC3 are level 3 temperature change due to mid-level convective latent heating and to penetrating convection, respectively, CLH is the latent heat to specific heat ratio (580/.24), and PREC is level 3 moisture change due to large-scale condensation.
28	Net Albedo	Computed from the ratio of two time-averaged variables. At each grid point, the time-averaged values of the following variables are collected: SCOSZ and RETOT where RETOT is the total reflected solar radiation, and SCOSZ is the total solar radiation at the top of the atmosphere. (See Sec. II for the formulation of RETOT.) The variable values are then formed using RETOT/SCOSZ. SURF is not used.

Tape Output

The important output of MAPGEN is the tape that contains the map data. For each map, a tape record is written describing the map data. These records are used as input to the Map Display Program, where the actual contour and zonal profile maps are drawn. If two experiments are to be compared, the data arrays can be input to the differencing program, which subtracts them, and Map Display can contour the differences.

The following information is put into each record by MAPGEN.

1. The start and end times in hours of the accumulation (2 words).
2. The (floating-point) weighting factor used to average the accumulations. If only one time point is used, this number is set to 1.0.
3. A 4-character identification, input in the M/A run.
4. The map number (integer).
5. The 52-character 13-word title of the map.
6. The sigma surface or pressure, SURF.
7. Two logical flags, one word each, stating whether the array data are on the π grid (the horizontal finite-difference grid) or the u,v wind velocity grid. See Ref. 1, p. 70.
8. A word no longer used.
9. The 46×72 array values.
10. The 46-word zonal mean of the variable.
11. The 46-word zonal mean of the variable over the oceans.
12. The global mean.

A dummy record of the same length is used to flag the end of the tape. The start and end times for this record are set to values over 100,000.

Punched Output

If the punched output for the zonal mean values is requested by the first card of the data set, then for each map in the data set, seven punched cards giving the zonal means and the global mean will be generated. The first three columns of the cards give the card

number, 0 through 6. The next six columns give the input (integer) experiment number and the map number, followed by the SURF value in columns 10-16. The first card gives the start and end times in columns 17-24 and 25-32. The next five cards have eight zonal mean values per card in columns 17 through 80, 8 columns per value, with the values given to thousandths. The last card has the last six zonal mean values plus the global mean in columns 65-72.

JOB CONTROL COMMENTS

The program is run at UCLA on the IBM 360/91. The program uses 1250K of core, and is compiled on the H-compiler. The map data, along with other information, is written onto FORTRAN unit 9, in this case a tape, in one large record for each map.

The disk data sets written by the M/A program are input on FORTRAN unit 8. Two disk data sets may have to be concatenated as one disk holds only about 23 days simulation time.

IV. USER'S GUIDE FOR MAP DISPLAY

Map Display outputs the data generated by MAPGEN. The data can be displayed in three ways: The array and affiliated statistics can be printed, a contour map can be drawn, or the zonal mean values can be graphed. The type or types of output are controlled by card input.

The choice of the isolines to be drawn in the contour map is very important. These values may be a personal choice, or may depend on the data; one experiment may need different isolines from another. This is one reason why Map Display and MAPGEN are two programs; the array data may be used to generate many different contour maps with different isolines. However, the isolines used in the standard output package are very good for most runs. (See Appendix A.)

INPUT DESCRIPTION

There are three types of input for Map Display: the map descriptions similar to the MAPGEN input, the land outlines for the contour maps, and the array data from MAPGEN. The first two types are input with cards, and the MAPGEN output is on tape or disk.

To obtain an outline of the continents used in the M/A program, a set of input cards must be prepared for the Map Display program. For each M/A grid point, a value is input: zero if the point is ocean, and nonzero if the point is land. Note that sea ice is considered ocean (0) and land ice is considered land (1).

The land mass data are input using 144 cards. For each of 72 meridians, two cards are used to describe the 46 latitude values along the meridian. The first card has 25 values in the first 75 columns in F3.0 format (0.0 or 1.0), starting with the South Pole, and the second card has the remaining 21 values in the first 63 columns in F3.0 format, ending at the North Pole. The 72 pairs of cards start at 180° W longitude and proceed eastward to 175° E.

The input data sets described in the MAPGEN section (pp. 16-19) are also used for Map Display. The first card of the data set and the map descriptions are the same as those described in the MAPGEN User's

Guide. However, the input is more flexible for Map Display. For one thing, one data set can consist of any number of map descriptions, while MAPGEN is limited to 40. Incidentally, the order of the map descriptions does not have to be the same as on tape; they can be put into any order desired. To match the data on tape, only the start and end times, the map number, and the SURF value need to be the same; all the other values in the map description can be different in the Map Display run. Thus, in one Map Display run, several contour maps using different isolines can be drawn using the same array data.

PRINTED OUTPUTS

Appendix B presents an example of the printout from the Map Display program. Each map printout consists of five pages of printed output, with a standard heading on each page.

The output heading consists of three lines of data. The first line gives the map number and the run title that were input in columns 2 through 77 of the first card of the input. The second line gives the map title, the SURF value, the contour interval, and the global mean. The SURF value is identified as S/P, which means sigma surface or pressure level, and the contour interval is called CONINT. The third line consists of the four-character identification input in the M/A run, time points sampled from the M/A disk by MAPGEN, and the starting and ending days.

The global mean is calculated by area weighting the zonal means. There are two sets of weighting functions, one for the standard π latitude/longitude grid and the other for the wind grid (which is called the u,v grid in the M/A model). The weighting function (wf) for the π -grid is defined by:

$$wf(L) = \begin{cases} 1 - \sin 88^\circ & \text{for } L = -90^\circ \text{ and } +90^\circ \\ \sin(L + 2^\circ) - \sin(L - 2^\circ) & \text{for } L = -86^\circ \text{ to } +86^\circ \end{cases}$$

where L proceeds from -90° to $+90^\circ$ by increments of 4° .

The weighting function for the u,v grid is given by:

$$wf(L) = \sin(L + 2^\circ) - \sin(L - 2^\circ) \text{ for } L = -88^\circ \text{ to } +88^\circ$$

where L goes from -88 to +88 by 4° increments.

The global average of a zonal mean, X(L), is then given by:

$$\frac{1}{2} \int_{-88}^{+88} wf(L) \cdot X(L)$$

The latitudes are printed on the left side of each page. The last row on the page, labeled AVG, represents the weighted meridional averages of the longitude. The longitude labels are directly under the page heading. The last page of output includes the zonal means and the zonal means over the oceans.

Whenever a local high or low value is found, an H or L is printed, respectively. In the case of the wind maps 5 and 6, these letters are replaced by W or E for map 5, and S or N for map 6.

The zonal means graph has the global mean printed at the right side of the graph. Below this, the zonal mean values are printed next to their respective latitudes. The line in the center of the graph area represents the zero value. The scale for the plot is determined by the zonal means themselves; the largest absolute value among the means is chosen as the scale factor. In the example in Fig. 2, the largest absolute value is -1.683, and thus the extreme left of the graph area is chosen to be -1.683 and the extreme right of the graph area is +1.683. The hash marks on the zero value line represent each of the 46 latitudes.

For map 7, which describes the sigma vertical velocity, an additional output is given. Zonal means of the horizontal mass flux of the simulation are printed with the other means. If a zonal mean graph for map 7 is to be plotted, the mass flux profile will be drawn, in addition to the graph of vertical velocity. A different map title is used for the horizontal mass flux profile. If ZM(J) is the original zonal mean then ZMF(J), the zonal mean of the horizontal mass flux, is defined by:

$$ZMF(J) = \begin{cases} 0.0 & \text{if } J = 1 \\ ZMF(J-1) - 2.52 * [ZM(J) * \cos(4^\circ * (J-1) - 86^\circ) \\ + ZM(J-1) * \cos(4^\circ * (J-2) - 86^\circ)] & \text{for } J = 2, 46 \end{cases}$$

The unit of measurement is 10^{13} gm/sec.

PLOT OUTPUT

Examples of the two plots drawn by Map Display are given as Figs. 1 and 2. Figure 1 is the contour map and Fig. 2 is the corresponding plot of zonal means.

The heading is similar to the printout heading. The first line consists of the map number and the run title. The second line starts with the map title. The SURF value is normally printed, either with "SIG =" if SURF is a sigma surface, or with "MB" following the value if SURF is a pressure level. For maps 1 and 14, SURF is not printed at all, as SURF is strictly a flag in these maps. Following this, on the same line, is the message ISOLINES AT, followed by the smallest isoline value and the contour interval. The third line starts out defining the time intervals, giving the start and end time in days. Next a four-character identification is printed, which was input during the M/A simulation run. Next the dashed-line isoline value is printed, preceded by the message DASHED LINE IS.

For maps which use the u,v grid, a warning message, GRID OFFSET, is written at the end of this line. That is because the contours are drawn as if the values are on the π -grid, when actually the contour lines are displaced one-half grid interval to the left and upward.

The contour map has the latitude values printed every 20 degrees on the right side of the map. At each grid point in the oceans, a dot is plotted so that the latitude and longitude are more easily read. The land outline is drawn between the land and water grid points. Ice is not indicated on the map.

JCB CONTROL COMMENTS

To draw the maps, Map Display uses a Rand-developed software system called the Integrated Graphics Systems (IGS), described in Ref. 2.

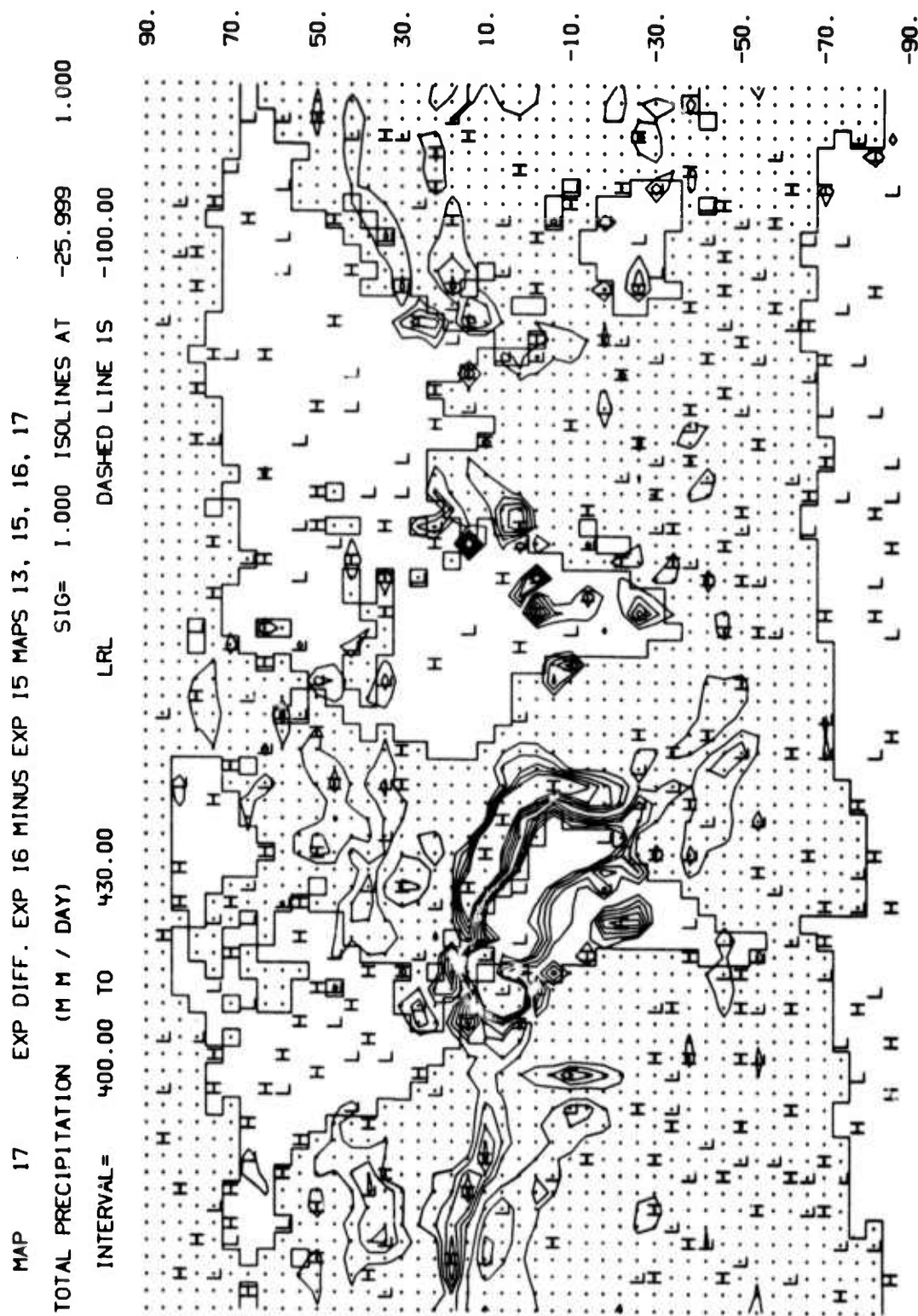


Fig. 1 — Sample contour map output by the Map Display program.
 The accompanying graph of the zonal means appears as Fig. 2.

MAP 17 EXP DIFF. EXP 16 MINUS EXP 15 MAPS 13, 15, 16, 17
 TOTAL PRECIPITATION (MM / DAY) SIG= 1.000
 INTERVAL= 400.00 TO 430.00 LRL

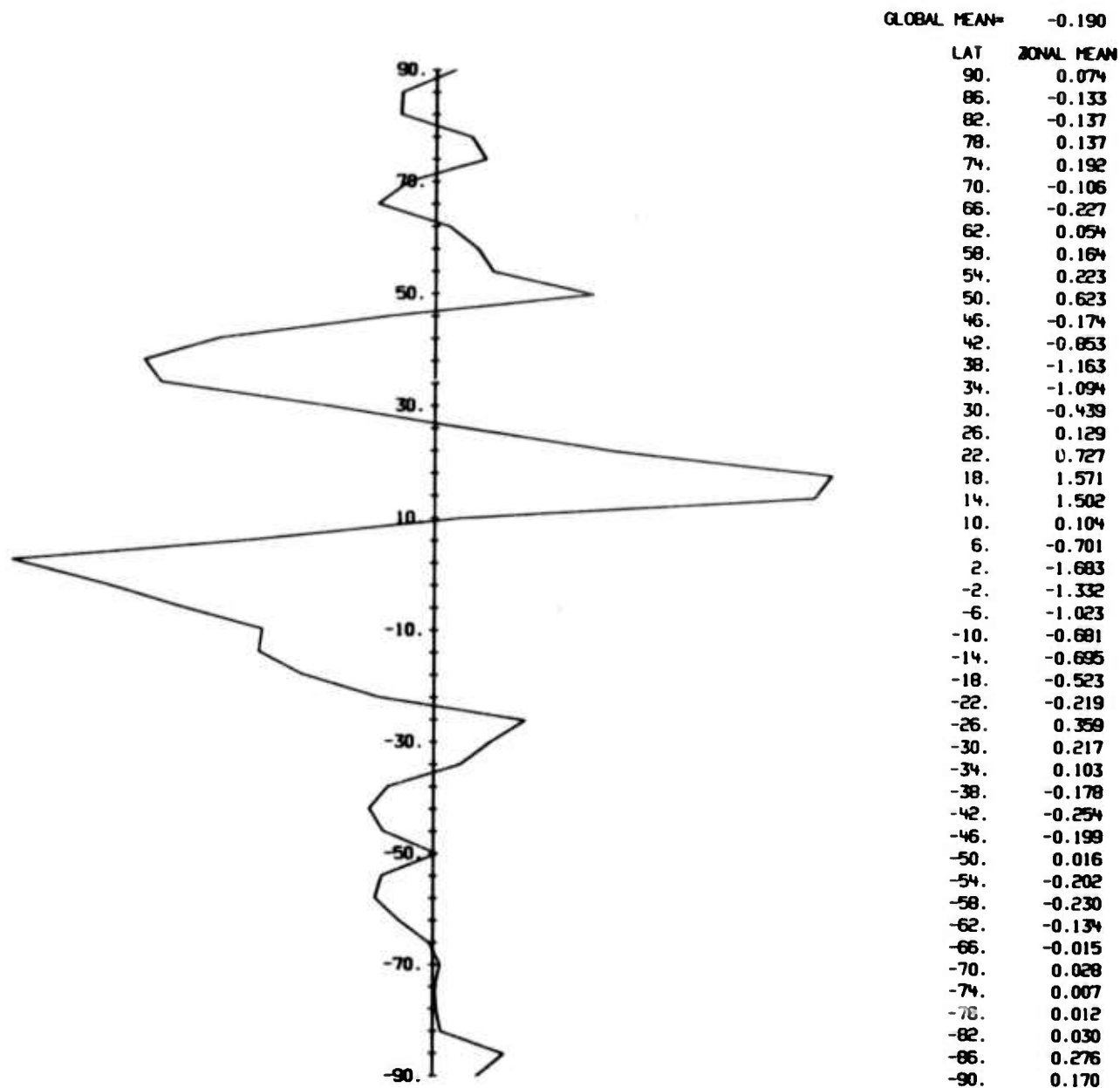


Fig. 2— Sample plot of zonal means output by the Map Display program.
 The accompanying contour map is shown as Fig. 1.

IGS writes a 7-track, 800 bpi tape, which can be used by an S-C 4060 graphical output device to draw the pictures on microfilm and print them on 11 x 14 paper.

The execution step uses three FORTRAN units. In Rand's operating system, the S-C 4060 output uses the file name SC4060ZZ. FORTRAN unit 8 is the output MAPGEN-type tape, and FORTRAN unit 9 is the input unit for the cards describing the land masses.

V. USER'S GUIDE FOR THE ZONAL PROFILE PROGRAM

The Zonal Profile program graphs the time averages of the zonal arrays written by the M/A program. The graphs are created directly with no intermediate steps. The flow of the program is determined by the use of control cards, described below.

The program produces graphs very similar to those created by the Map Display program. However, the graph scale used by the Zonal Profile program is fixed, so that the profiles of variables from different experiments can be compared in magnitude as well as in shape. The zonal mean values are printed out automatically for each graph.

PROFILE DESCRIPTIONS

The zonal arrays written by the M/A program are used to form 32 different profile graphs. For a given time interval, only one profile can be drawn for each profile number.

The formulas describing the profiles are given by Table 12. The mnemonics used are given in Sec. II, and represent the zonal mean arrays after they have been multiplied by the constants given in Table 7. The profile titles and the nominal scale factors are also given by Table 12.

For convenience, some of the profile values are printed in two different units. For profiles 1-5 and 7-16, the values are given in terms of langleys per day and langleys per thousand minutes (KMIN). A sample profile graph is given in Fig. 3.

INPUT DESCRIPTIONS

The Zonal Profile program uses control cards input by the user to control the input and execution of the program.

Nine types of control cards are built into the Zonal Profile program. Only the first four columns are used to identify the control card, with the other 76 columns free for comments. If the program is expecting a control card and does not recognize the next card as a control card, the card is still printed, and three lines are then

Table 12
ZONAL PROFILES AVAILABLE

Profile Number	Scales		Title	Formula
	Left	Right		
1	0	1600	Insolation at the top of the Atmosphere (ly/day, ly/kmin)	SCØSZ
2	0	100	Short-Wave Absorption above the Troposphere (ly/day, ly/kmin)	STRA
3	0	800	Short-Wave Absorption in the Troposphere (ly/day, ly/kmin)	AS1 + AS3
4	0	800	Total Short-Wave Absorption in the Atmosphere (ly/day, ly/kmin)	AS1 + AS3 + STRA
5	0	1600	Total Reflection in the Earth-Atmosphere System (ly/day, ly/kmin)	RETØT
6	0	1.0	Albedo (unitless)	RETØT/SCØSZ
7	0	800	Short-Wave Absorption by the Earth (ly/day, ly/kmin)	S4
8	0	800	Effective Long-Wave Radiation from the Earth (ly/day, ly/kmin)	R4
9	0	800	Long-Wave Radiation Lost to Space (ly/day, ly/kmin)	RO
10	0	800	Effective Long-Wave Radiation Lost from Atmosphere (ly/day, ly/kmin)	RO - R4
11	-200	600	Heat Lost by Evaporation from the Earth (ly/day, ly/kmin)	E4 * L/10
12	-400	400	Sensible Heat Loss from the Earth (ly/day, ly/kmin)	F4
13	-300	500	Energy Balance of the Earth (ly/day, ly/kmin)	S4 - R4 - E4 * L/10 + CICE
14	-800	0	Radiation Balance of the Atmosphere (ly/day, ly/kmin)	R4 - RO + AS1 + AS3
15	-400	400	Energy Balance of the Atmosphere (ly/day, ly/kmin)	R4 - RO + AS1 + AS3 + F4 + PPTØT * L/10 - E4 * L/10
16	-300	500	Energy Balance of the Earth-Atmosphere System (ly/day, ly/kmin)	S4 + AS1 + AS3 - RO + CICE + PPTØT * L/10
17	-1	9	Evaporation (mm/day)	E4
18	0	10	Precipitation (mm/day)	PPTØT
19	-5	5	Moisture Balance of the Atmosphere (mm/day)	E4 - PPTØT
20	0	4	Latent Heating at Sigma 3/4 (deg/day)	HL3
21	0	4	Latent Heating at Sigma 1/4 (deg/day)	HL1
22	0	4	Short-Wave Heating at Sigma 3/4 (deg/day)	HSW3
23	0	4	Short-Wave Heating at Sigma 1/4 (deg/day)	HSW1
24	-4	0	Long-Wave Heating at Sigma 3/4 (deg/day)	HLW3
25	-4	0	Long-Wave Heating at Sigma 1/4 (deg/day)	HLW1
26	-2	2	Sensible Heat from the Earth (deg/day)	HF4
27	-2	2	Total Heating at Sigma 3/4 (deg/day)	HL3 + HSW3 + HLW3 + HF4 or HDIF + (HL3 + HSW3 + HLW3 + HF4)/2.0 - (HL1 + HSW1 + HLW1)/2.0
28	-2	2	Total Heating at Sigma 1/4 (deg/day)	HL1 + HSW1 + HLW1 or HDIF + (HL1 + HSW1 + HLW1)/2.0 - (HL3 + HSW3 + HLW3 + HF4)/2.0
29	0	1	CL1 -- Deep Convective Cloudiness	CL1
30	0	1	CL2 -- Large-Scale Cloudiness	CL2
31	0	1	CL3 -- Low-Level Convective Cloudiness	CL3
32	0	1	CL -- Total Cloudiness	CL

PROFILE 19 EXPERIMENT 15 - SAHARA LAKE - SEPT 1972

RAND

MOISTURE BALANCE OF THE ATMOSPHERE (MM/DAY)

TIME = 370.00 TO 400.00

RANGE IS FROM

-5.00 TO

RRR

5.00

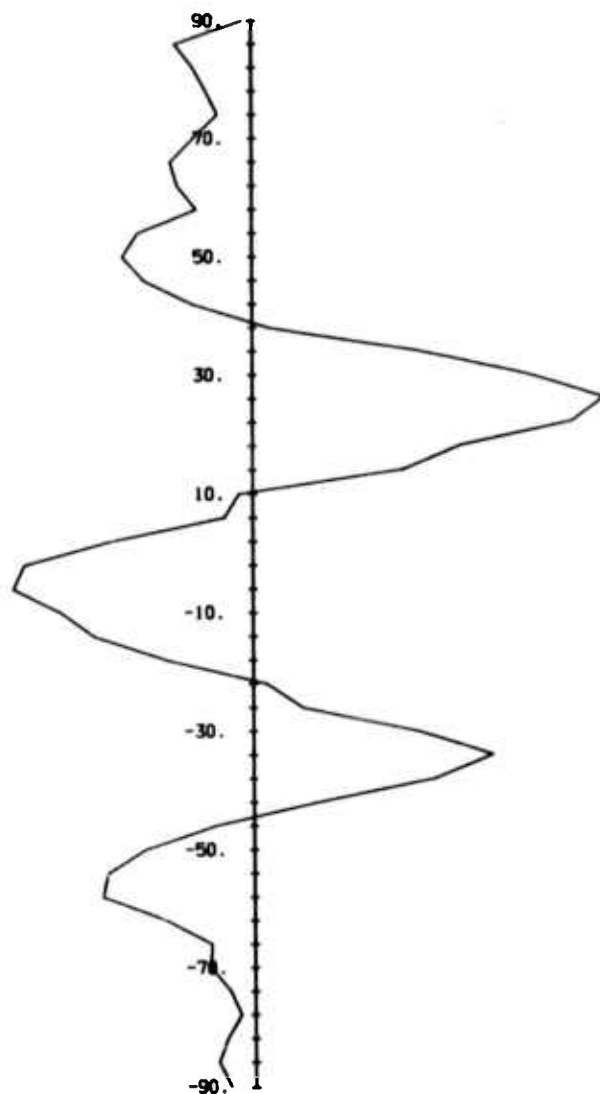
NO. MEAN = 0.562

SO. MEAN = -0.508

GLOBAL MEAN =

0.027

LAT ZONAL MEANS



90.	-0.103
86.	-0.852
82.	-0.654
78.	-0.507
74.	-0.379
70.	-0.656
66.	-0.908
62.	-0.836
58.	-0.621
54.	-1.276
50.	-1.442
46.	-1.204
42.	-0.663
38.	0.192
34.	1.823
30.	3.008
26.	3.870
22.	3.504
18.	2.274
14.	1.669
10.	-0.151
6.	-0.316
2.	-1.582
-2.	-2.525
-6.	-2.638
-10.	-2.117
-14.	-1.763
-18.	-0.964
-22.	0.168
-26.	0.567
-30.	1.812
-34.	2.624
-38.	1.993
-42.	0.719
-46.	-0.422
-50.	-1.213
-54.	-1.629
-58.	-1.685
-62.	-0.980
-66.	-0.479
-70.	-0.494
-74.	-0.269
-78.	-0.154
-82.	-0.311
-86.	-0.410
-90.	-0.273

Fig.3— Sample graph output by the Zonal Profile program

skipped in the printout to indicate the possible error. This continues until a control card is found.

The control card DATA controls the input of the profile descriptions. For each graph to be generated, the profile number, the start and end times, the delta time (measurement interval), and the four-character identification code word must be input.

To simplify the DATA card input, the user can input default values, or standard values. The user will in many cases wish to generate several profiles for the same time period, possibly using the same four-character identification code word. The user then inputs a default set of time values, plus a default code word, and need input only the profile number for the profile description. The code word serves no computational purpose; it is four arbitrary characters that the user can have printed on each graph for identification purposes.

The *delta time* tells how often to plot the accumulated profile values, input in units of days, so that more than one profile can be drawn with one profile description. If the delta time is zero, then one profile is drawn, using the full start to end time accumulation. If snapshots are desired, the delta time must be equal to the increment on disk (.25 day). For instance, if four profiles are wanted between 370.0 and 371.0 days, the three numbers to input are 370.0, 371.0 and .25 days.

A running count of the number of profile descriptions is kept, so that the standard values can be changed during a run. Suppose the standard values are used and two 30-day accumulations are desired. Then the standard values are input for the first 30 days, and the DATA control card reads in the descriptions for the 32 maps. In this case, only the profile numbers need to be input, as standard times and code words are used. Then the next standard times for the next 30 days are input and the DATA card is again used, again with only the profile numbers 1 through 32 on the cards. This procedure has input the data for 64 maps. The program has a limit of 128 profile descriptions for one reading of the M/A disk, but these sets of profiles can be repeated as many times as desired in one run.

Nine control cards are as follows:

TITLE: The card following this has the run title in columns 1-72. This title is printed on each subsequent profile and printout. Only one title is used for each set of profiles. The program expects a control card after the title.

DATA: This card tells the program that the profile descriptions follow. The profile descriptions are terminated by a blank card, after which the program expects another control card. Each of the five data elements uses 10 columns. The profile number is an integer, right adjusted in columns 1-10. The start, end, and delta times which follow the profile number are floating-point values. The code word is input in columns 47 through 50. If the start or end time is not a multiple of .25 day, or the delta time is greater than .25 day and is not a multiple of .25 day, an error message is written and the profile description is deleted.

The number of input profile descriptions, NMAP, cannot be over 128, but more profile descriptions can be accumulated again after the 128 are executed, by resetting NMAP to zero and reading in more data cards.

NMAP: This card resets the number of input profile descriptions. The number is input right adjusted in columns 1-10 of the next card. If a second set of profiles is to be generated by the GO control card, the number of descriptions has to be reset to zero. If the NMAP card is used to input a negative number, then the number of profile descriptions is reduced by that amount. The program expects a control card after the one data card.

CODE: This card sets a default four-character code word for the DATA cards. If the code word for the data description is blank, this word is inserted. It will usually be used to input the initials of the interested researcher for identification purposes. The code word is input in columns 1-4 of the next card.

STANDARD: The default start, end, and delta times are read in following this card. The data elements use 10 columns each, and are floating-point values, starting in column 1.

SCALES: This control card changes at least one of the default profile scales. For a specific experiment, the built-in scales of the

graph area may not be appropriate, and they can be changed here. One new scale is input per card; the data cards are followed by a blank card. The profile type number is input as a right-adjusted integer in columns 1-10, the left graph value in columns 11-20, and the right graph value is columns 21-30. Both values are input as floating-point numbers.

GO: This control card tells the program to execute the profiles that have been input. No data cards are input for this control card. The profile descriptions are printed out, and then the graphs and printout generated. After all the profiles are done, the program returns to process more control cards.

NUMZON: This control card determines the number of zonal mean arrays in the input data sets. Default is 24 arrays. Note: Experiments 10-13 have 24 arrays, experiments 14-17 have 25 arrays.

STOP: The program must end with this control card for normal termination. No cards are read beyond this control card.

Table 13 gives a short description of each of the control cards, with the number and format(s) of the data cards which follow each.

Table 13
CONTROL WORDS FOR THE ZONAL PROFILE PROGRAM

Control Word	Description	Number of Data Cards	Format of Data
TITLE	Run title	1	18A4
DATA	Profile descriptions--No., times, ID	N	I10, 6X, A4 3F10.0
CØDE	Standard 4-character identification code word	1	A4
STANDARD	Standard start, end, and delta times	1	3F10.0
SCALES	Change profile scales	N	I10, 2F10.0
GØ	Print out input and execute	0	None
NMAP	Change the number of input profile descriptions	1	I10
NUMZØN	Set the number of zonal means	1	I0
STØP	End program normally	0	None

SAMPLE INPUT RUN

The card input listing in Fig. 4 is a valid input deck for the Zonal Profile program. First the title is input, followed by the standard times and code words. The data will be accumulated from day 340 to day 370, arbitrarily using the identification code STD, standing for the standard output. The DATA control card then inputs all 32 profiles, using the standard values. Note that only the profile numbers are input in this section.

As the rest of the maps for this pass are not standard, the code word is changed from STD to DSP. Then three profile descriptions are input; thus 35 profile descriptions have been input. The first of the new descriptions draws five graphs of profile No. 5 at the times 399.0, 399.25, 399.5, 399.75, and 400.0. As the M/A program accumulates these values, the maps represent six-hour accumulations, even though only one time point is read from disk for each.

The next profile description generates one graph, and accumulates the data for profile 8 between 395 and 400 days, with the code word WLG used. Again, the accumulation averages the disk time points 395.25 to 400.0.

The last profile description generates nine graphs of profile 10, using the nonstandard code word DSP. The times are 390 to 391, etc. Each accumulation uses four disk time sets for each day.

The control card GO then outputs the input profile descriptions, the scales, etc., and the profiles are generated. After the profiles are drawn, control is again returned to the input cards. The number of profile descriptions is reset to zero, and new standard values are input. In this case, the values are to be accumulated for 30 days, between day 400 and day 430, using the code name STD for all of the 32 profiles. These profiles are then executed with the GO control card, and the program ends with the STOP control card.

```

//GO.SYSIN DD *
THIS IS A SAMPLE INPUT DECK FOR THE ZONAL PROFILE PROGRAM.
THE INPUT IN EXACTLY THIS FORM WILL EXECUTE.
TITLE - INPUT THE RUN TITLE
NEW CONTROL - EXPERIMENT NO. 10 FIRST 30 DAYS FEB 72 RAND
STANDARD TIMES - 340.0,370.0,400.0,430.0 ARE KEY 30 DAYS AVERAGE TIMES
340.0 370.0
CODE NAME INPUT - FOR STANDARD RUN MAPS
STO
DATA - INPUT 1-32 PROFILES USING STANDARD VALUES
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32

CODE NAME - NEXT MAPS ARE NOT STANDARD OUTPUT
OSP

DATA - CONTINUE TO INPUT PROFILE DESCRIPTIONS
5 398.75 400.0 0.25 WLG
8 395.0 400.0
10 390.0 400.0 1.0

GO EXECUTE THESE PROFILE DESCRIPTIONS
UP TO 128 DESCRIPTIONS CAN BE INPUT IN THE GO STEP. BUT FOR AN EXAMPLE.....
MAP - SET THE NO. OF INPUT DESCRIPTIONS TO ZERO FOR MORE MAPS
0
STANDARD TIMES - ANOTHER 30 DAY AVERAGE
400.0 430.0
CODE NAME - STANDARD INPUT AGAIN
STO
DATA

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32

GO EXECUTE THESE MAPS.
STOP ***** ANYTHING CAN GO HERE - THE PROGRAM ONES NOT READ THESE CARDS
/

```

Fig. 4— Sample input for Zonal Profile program

VI. USER'S GUIDE FOR THE QUICK LOOK PROGRAM

Quick Look is designed to help the programmer and researcher to decide if the M/A program is running correctly. At checkpoints throughout the simulation, the M/A program may be stopped and the data on disk inspected to determine if the program is behaving as expected. The Quick Look program was designed primarily to do this.

Quick Look reads both the large array data set and the zonal mean data set. The program also has a limited capability of accumulating values; the three precipitation arrays are accumulated to form the total precipitation values, and all the zonal mean arrays can be accumulated. Of course, logic can be added to accumulate any of the arrays on the disk, but only those mentioned are automatically implemented.

At a specified time point, the program will print out all the restart arrays: P, U1, U3, V1, V3, T1, T3, Q3, GW, and GT. The user inputs the start and end times of the disk, and at every Nth time point, where N is input by the user, values at a specified grid point from each large array are printed together with all the zonal mean arrays (accumulated from the previous six hours).

CARD INPUT

The first card of the input is a title, 80 columns long. The next cards describe the printout. The start and end times are given in columns 11-12 and 13-24, respectively. Time is input in days, and must be exactly the same as on the disk. Columns 25-36, right adjusted, give the integer number N, which controls the printout of the large arrays at the specified grid point and the snapshot of the zonal mean arrays. Columns 37-48, right adjusted, hold the integer flag for the accumulations over the entire time period. If it is zero, no accumulations are done; if not zero, the zonal means are accumulated and printed out. If the integer flag value is above 9, then the total precipitation values are also accumulated.

The time at which to print all the restart arrays is set within the program by a variable (PRTALL). This must be set by the programmer or researcher before compilation.

The Quick Look program executes the one-card instruction, and then looks for another data card. The one limitation on this following card is that its starting time must be greater than the ending time on the previous card. The program is terminated by a blank card.

PRINTOUT DESCRIPTION

Suppose the start and end times are 405 and 410, N is set to 200, and the flag set to 10. Then at day 405, the array grid-point values are printed out, followed by the zonal mean values accumulated for the previous six hours. The grid-point values are printed out at -14° latitude and 35° W longitude, corresponding to the latitude grid number 20 and longitude grid number 30. (This grid point can, of course, be easily changed within the program to any other grid point.) Since N was set to 200, this printout would be repeated after 200 disk time points, or 50 days, but as the end time come before then, this printout is done only at the start time, day 405.

Supposing that the print time, PRTALL, was set to 410, all the restart arrays and precipitation arrays are printed out at that time. Each array takes eight pages to print out; an eight-character identification for each array is built into the program and is printed at the top of each page. Next the accumulated zonal arrays are printed out, preceded by the title and the start and end times of the accumulation. The 24 zonal arrays are printed, each value preceded by its latitude, with a built-in four-character identification given as a heading. After this, the precipitation array is printed. Note that the zonal array values are always printed out after being multiplied by the conversion constants given in Table 7.

Two subroutines are included in the Quick Look program to do the printing of the large arrays and the zonal means. The array and a short name are input to the routines and the data are printed out. The printout of the large arrays gives the latitude and longitude of the rows and columns. Each data value is printed with five-place accuracy. The zonal arrays are printed next to the latitude values.

As a bonus, other data are automatically printed out. The first time that TAU and the constant C-array (see Sec. II) are read, all 800 constants of this C-array are printed out in three forms: as integers, binary-coded decimal characters, and floating-point values. The 24 or 25 constants used in converting zonal mean arrays are also printed out.

By adding one card, a feature can be used which really helps the researcher and/or programmer analyze the output. The topography array TOPOG gives the sea, land, and ice areas of the Earth. Within the program, this array is changed by setting 0.0 to represent ocean, 1.1111 to represent ice, and 9.9999 to represent land. The resultant array can be printed by adding one card, so that the user can determine at a glance whether a particular grid point is ocean, land, or ice.

JOB CONTROL COMMENTS

The Quick Look program uses less than 150K bytes of core, and takes less than two minutes to run on the 360/91. The number of pages generated may be very large, depending on what is being printed out. The restart disk data set is input on unit 10, and the zonal disk data set is input on unit 11. By concatenating data sets, 20 days or more can be investigated on one pass.

VII. USER'S GUIDE FOR THE DISK INITIALIZER PROGRAM

The Disk Initializer program is used in conjunction with the M/A program. It will read a time history up to a specified time point, then write the data onto a new disk so that the M/A program can continue its simulation. Because of the way the M/A program is written, it is easier and safer to use this program rather than the M/A program itself to switch disks when writing the time history data sets.

Disk Initializer has other uses, too. It can easily be modified to set up the initial conditions of a new experiment. Suppose the new experiment modifies the topography array; then the Initializer can read in the new values and initialize the new disk using these values. For printout purposes, the subroutine in the Quick Look program that prints out the large arrays can be copied and added to Disk Initializer to print out the old and new topography arrays.

Disk Initializer is useful in emergency situations. No computer is perfect, and when a program uses 30 hours of CPU time, it is exposed to a chance of malfunction. Sometimes a special emergency program has to be written to save all or part of an M/A disk; Disk Initializer can be used as a basis for the new program.

Disk Initializer uses 400K of core and less than one minute of CPU time. The old restart data set is on unit 11, the old zonal data set is on unit 13, the new restart data set is on unit 12, the new zonal data set is on unit 14, and the new last-time record is on unit 1. The time, in days, to read up to and write on the new units is set by the variable DAYS within the program itself. There are no cards input to this program.

VIII. USER'S GUIDE FOR THE DIFFERENCE PROGRAM

The Difference program is used in conjunction with MAPGEN and Map Display for the purpose of comparing two maps. Unlike the other two auxiliary programs, the Difference program is relatively stable and will not normally change from experiment to experiment.

Two tapes from MAPGEN runs are used as input to generate a third tape giving the differences of values on the original two tapes. This third tape can then be used as input to the Map Display program.

The card input is identical to the MAPGEN card input in format: a title card, followed by data sets consisting of the first-card time description, followed by the map descriptions. The map descriptions do not have to be in the same order as in MAPGEN, and the limit of 40 map descriptions per set does not apply.

The values differenced are the large 46×72 data arrays, the zonal means, the zonal means over the ocean, and the global means. The values from the "low" tape, the one on FORTRAN unit 10, are subtracted from the values from the "high" tape, on unit 9, and the differences put on the output tape on unit 11. Only the map descriptions input on cards are written on the tape. To match the two sets of values, the start and end times, the map number, and the SURF values must be the same. For each map, the values written on the output tape, such as the ID, the map title, and the number of accumulations, are the same as on the high tape.

The Difference program uses less than 150K bytes of core and takes less than two minutes of CPU time on the IBM 360/91.

APPENDIX A
LISTING OF STANDARD INPUT PACKAGE
FOR
MAPGEN AND MAP DISPLAY

THIS IS THE STANDARD INPUT PACKAGE FOR MAPGEN AND
 MAP DISPLAY. COLUMNS 1-2 - MAP NUMBER COLUMNS 3-7 -
 SURF COLUMNS 8-12 - CONTOUR INTERVAL COLUMNS 13-17 -
 DOTTED LINE COLUMNS 23-27 - NO. OF PRINTOUTS COLUMNS
 28-32 - FLAG FOR USERS CONTOUR VALUES COLUMNS 33-37 -
 ZONAL MAP FLAG COLUMNS 38-42 - CONTOUR MAP FLAG

THE FOLLOWING FORMS ALL 3 TYPES OF OUTPUT IN MAP
 DISPLAY.

0000000011111111112222222222333333333344444444445555555555666666666677777777778
 1234567890123456789012345678901234567890123456789012345678901234567890

3 EXP. 10 - CONTROL EXPERIMENT - MARCH 72 - RAND

	370.0	400.0			
1	1.0	2.0	20.	0.0	1.0
1	3.0	10.	30.	0.0	1.0
2	1.0	5.0	0.0	0.0	1.0
3	.25	10.	400.	0.0	1.0
3	.75	20.	800.	0.0	1.0
3	1.0	40.	1000.	0.0	1.0
4	.25	1.0	70.	0.0	1.0
4	.75	2.5	75.	0.0	1.0
4	400.	1.0	70.	0.0	1.0
4	800.	.5	20.	0.0	1.0
5	.25	5.	0.	0.0	1.0
5	.75	5.	.0	0.0	1.0
5	400.	5.	0.0	0.0	1.0
5	800.	5.	0.0	0.0	1.0
5	.25	5.	0.0	0.0	1.0
5	.75	5.	0.0	0.0	1.0
5	400.	5.	0.0	0.0	1.0
5	800.	5.	0.0	0.0	1.0
7	.5	10.	0.0	0.0	1.0
8	1.	5.	0.0	0.0	1.0

	370.0	400.0			
9	1.0	5.0	0.0	0.0	1.0
10	.25	5.	-20.	0.0	1.0
10	.75	5.	0.0	0.0	1.0
10	400.	5.	-20.	0.0	1.0
10	800.	5.	0.	0.0	1.0
11	1.	2.	5.	0.0	1.0
12	.75	20.	50.	0.0	1.0
13	1.	1.	1.	0.0	1.0
14	.25	.04	.12	0.0	1.0
14	.75	.3	.5	0.0	1.0
14	1.0	.3	.5	0.0	1.0
14	2.0	.3	.5	0.0	1.0
15	1.0	2.0	4.0	0.0	1.0
15	1.0	10.0	20.	0.0	1.0
17	1.0	10.	20.	0.0	1.0
18	1.0	5.	10.	0.0	1.0
19	1.0	1.0	-1.0	0.0	1.0
20	1.0	10.	0.0	0.0	1.0
21	1.0	2.0	10.	0.0	1.0
22	1.0	.5	0.0	0.0	1.0
23	1.0	2.0	0.0	0.0	1.0
24	.25	.2	0.0	0.0	1.0
24	.75	.2	0.0	0.0	1.0
25	.25	.5	2.0	0.0	1.0
25	.75	.5	2.0	0.0	1.0
25	.25	.5	0.0	0.0	1.0
25	.75	.5	0.0	0.0	1.0
27	.25	5.	0.0	0.0	1.0
27	.75	5.	0.0	0.0	1.0
28	1.0	5.0	10.	0.0	1.0

0000000011111111112222222222333333333344444444445555555555666666666677777777778
 1234567890123456789012345678901234567890123456789012345678901234567890

APPENDIX B
DATA PRINTOUT FOR MAP DISPLAY OUTPUT
FOR ONE VARIABLE

MAP NO. = 10
TEMPERATURE (DEGREES CENTIGRADE)
EXP. 11 - MOUTPAC II - MARCH 72 - PAND
S/P = 600.300 CONTIN = 5.000 GLOBAL MEAN = 0.27344E 00
120.0 SAMPLES Y = 370.000 TO 400.000

LAT	105W	100W	95W	90W	85W	80W	75W	70W	65W	60W	55W	50W	45W	40W	35W
90	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622
86	-47.475	-46.512	-46.558	-46.566	-46.261	-45.879	-45.785	-45.886	-45.703	-45.298	-44.772	-44.495	-44.231	-44.007	-43.861
82	-47.340	-47.405	-48.078	-47.210	-47.983	-47.563	-46.594	-47.214	-45.146	-45.513	-44.449	-41.628	-39.871	-37.897	-35.212
78	-45.146	-45.750	-46.051	-46.814	-47.038	-46.918	-46.172	-45.040	-43.522	-42.121	-39.708	-36.988	-34.536	-32.183	-28.432
74	-45.912	-46.274	-43.055	-43.785	-44.462	-43.471	-43.142	-42.223	-40.854	-38.270	-34.826	-30.465	-26.458	-23.540	-20.655
70	-34.450	-36.128	-37.890	-38.952	-39.686	-40.174	-39.618	-39.127	-37.157	-34.848	-28.935	-23.613	-19.801	-17.974	-17.132
66	-27.503	-30.050	-32.152	-34.358	-35.636	-36.443	-36.139	-35.590	-33.168	-28.611	-22.591	-18.215	-15.429	-15.213	-13.558
62	-22.616	-25.341	-28.240	-30.795	-32.484	-33.764	-34.279	-33.412	-31.255	-23.939	-18.336	-14.707	-13.803	-13.054	-12.212
58	-16.243	-21.558	-24.795	-27.516	-29.850	-31.268	-32.482	-32.623	-32.312	-28.002	-20.226	-16.810	-15.215	-14.163	-12.752
54	-18.156	-19.654	-21.494	-24.546	-26.490	-28.927	-30.430	-32.608	-31.822	-24.877	-21.176	-18.841	-16.501	-14.266	-14.166
50	-15.852	-17.280	-19.561	-21.114	-23.712	-25.400	-27.864	-28.853	-31.412	-27.205	-26.539	-23.084	-20.059	-17.043	-14.166
46	-12.641	-13.948	-14.915	-16.485	-17.241	-19.346	-21.672	-22.575	-24.016	-23.135	-21.585	-19.539	-17.228	-14.086	-10.846
42	-10.236	-10.472	-11.116	-12.209	-13.531	-13.981	-15.463	-15.605	-15.924	-15.388	-14.104	-13.065	-10.764	-8.035	-5.418
38	-7.244	-7.152	-6.978	-7.429	-7.572	-7.941	-7.984	-7.935	-7.397	-6.814	-6.141	-5.120	-3.735	-2.029	-0.265
34	-2.775	-2.667	-2.468	-2.392	-2.065	-1.945	-1.593	-1.327	-1.035	-0.641	-0.211	0.485	1.148	2.068	2.927
30	-1.266	-1.959	-2.291	-2.566	-2.908	-3.302	-3.730	-3.903	-3.994	-4.294	-4.520	-4.570	-4.865	-5.214	-5.455
26	7.066	9.747	9.345	10.505	10.284	7.389	8.191	8.189	8.124	8.027	7.875	7.831	7.682	7.540	7.374
22	9.982	11.018	12.267	14.080	12.667	12.011	11.790	13.458	11.603	11.365	11.187	11.027	10.786	10.369	9.758
18	10.518	11.396	11.671	14.674	14.736	11.927	12.075	12.166	11.886	11.907	11.827	11.652	11.464	11.258	10.890
14	10.441	11.074	11.640	12.328	12.283	11.575	11.813	11.046	11.241	12.048	12.197	12.105	11.931	11.776	11.578
10	10.726	10.881	11.139	11.474	11.561	11.374	10.251	11.127	11.725	11.875	12.243	12.256	12.338	12.182	12.064
6	10.515	10.501	10.809	11.006	11.135	10.739	10.320	11.889	12.241	12.217	12.275	12.304	12.320	12.354	12.273
-2	10.526	10.636	10.726	10.785	10.520	9.929	11.508	12.541	12.539	12.276	12.392	12.509	12.495	12.368	12.339
-6	10.826	10.825	10.710	11.106	11.038	10.416	11.864	12.919	12.858	12.572	12.528	12.621	12.513	12.374	12.271
-10	10.375	10.576	9.956	10.382	10.900	12.127	11.568	13.706	13.686	13.185	12.977	12.815	12.520	12.249	12.005
-14	10.710	10.248	9.403	9.144	9.383	10.306	10.973	14.441	14.433	13.947	13.544	13.257	12.625	12.139	12.059
-18	10.126	9.843	9.275	8.961	8.770	8.877	9.803	15.999	17.548	15.269	14.179	14.189	12.980	12.059	11.741
-22	5.239	8.654	8.346	8.021	7.949	7.564	8.663	12.457	14.844	16.835	14.571	16.529	13.266	11.918	11.233
-26	6.158	7.708	7.211	6.913	6.785	6.450	6.638	9.575	11.754	12.752	14.264	14.633	11.758	10.571	9.910
-30	6.708	6.268	5.951	5.510	5.365	4.858	4.792	6.677	8.773	9.866	11.515	10.341	9.257	8.256	7.615
-34	4.656	4.355	4.027	3.745	3.538	3.284	2.981	3.946	6.003	7.212	8.624	7.702	6.597	5.615	4.779
-38	2.580	2.592	2.219	1.990	1.484	1.525	0.834	1.894	3.392	5.137	4.648	4.261	3.326	2.285	1.459
-42	1.025	0.838	0.639	0.440	0.126	-0.003	-0.287	0.461	2.129	1.964	1.398	0.885	-0.093	-1.031	-1.702
-46	-1.223	-1.811	-2.290	-2.528	-2.611	-2.236	-2.157	-1.642	-0.946	-1.076	-1.553	-2.133	-2.833	-3.584	-4.446
-50	-3.165	-3.863	-4.621	-5.157	-5.624	-5.485	-5.319	-4.901	-4.242	-4.331	-4.751	-4.971	-5.441	-5.924	-6.744
-54	-5.108	-6.069	-6.841	-7.675	-7.762	-7.408	-7.156	-7.092	-6.788	-6.961	-7.278	-7.587	-7.785	-7.999	-8.464
-58	-8.843	-9.748	-10.397	-10.791	-10.893	-10.529	-10.231	-9.546	-9.088	-8.901	-9.147	-9.184	-9.283	-8.658	-8.361
-62	-11.592	-12.502	-12.889	-12.943	-12.784	-12.529	-11.887	-11.442	-11.192	-11.153	-11.318	-11.504	-11.324	-11.017	-10.324
-66	-14.125	-14.532	-14.870	-14.566	-14.354	-14.602	-14.463	-14.199	-14.517	-14.024	-13.759	-12.982	-12.374	-11.940	-11.637
-70	-16.538	-16.420	-16.289	-16.156	-16.366	-16.886	-16.929	-17.572	-17.293	-16.600	-16.511	-15.765	-14.831	-14.702	-14.399
-74	-19.174	-18.952	-18.960	-18.701	-16.488	-16.886	-17.309	-17.368	-17.682	-17.329	-17.563	-17.346	-16.219	-15.893	-15.988
-78	-19.174	-18.509	-18.489	-18.266	-18.370	-17.987	-18.246	-18.562	-19.187	-18.592	-18.356	-18.095	-17.555	-17.043	-16.528
-82	-18.572	-18.543	-18.547	-18.466	-19.446	-18.990	-19.449	-19.422	-19.644	-19.616	-19.646	-18.810	-18.015	-17.115	-16.710
-86	-18.484	-18.549	-18.972	-19.661	-20.547	-20.651	-20.338	-20.003	-19.482	-19.653	-19.994	-20.045	-19.989	-19.969	-19.794
-90	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227
AVE	-0.544	-0.759	-1.160	-1.335	-1.608	-1.910	-1.965	-1.028	-0.558	0.044	0.719	1.277	1.352	1.518	1.761

FAP NO. = 10
TEMPERATURE (CENTIGRADE)
MLH

EXP. 11 - MUTPAC 11 - MARCH 72 - RANO
S/P = 300.000 CONTIN = 5.000 GLOBAL MEAN = 0.27344E UO
120.0 SAMPLES T = 370.000 TO 400.000

LAT	30N	20N	10N	5N	0E	5E	10E	15E	20E	25E	30E	35E	40E
90	-5.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622
85	-3.742	-43.778	-43.696	-43.458	-43.343	-43.339	-43.334	-43.334	-43.334	-43.334	-43.334	-43.334	-43.334
80	-3.470	-32.816	-32.254	-32.858	-32.858	-32.858	-32.858	-32.858	-32.858	-32.858	-32.858	-32.858	-32.858
75	-5.547	-24.553	-24.159	-24.478	-24.457	-24.457	-24.457	-24.457	-24.457	-24.457	-24.457	-24.457	-24.457
70	-19.571	-18.413	-17.855	-18.508	-18.508	-18.508	-18.508	-18.508	-18.508	-18.508	-18.508	-18.508	-18.508
65	-16.114	-14.900	-13.934	-14.468	-15.063	-15.063	-15.063	-15.063	-15.063	-15.063	-15.063	-15.063	-15.063
60	-12.141	-10.506	-10.538	-10.538	-11.538	-11.538	-11.538	-11.538	-11.538	-11.538	-11.538	-11.538	-11.538
55	-11.241	-8.329	-8.084	-8.451	-8.390	-8.390	-8.390	-8.390	-8.390	-8.390	-8.390	-8.390	-8.390
50	-11.762	-7.226	-5.115	-7.594	-8.190	-8.190	-8.190	-8.190	-8.190	-8.190	-8.190	-8.190	-8.190
45	-11.223	-8.137	-3.272	-4.417	-5.786	-8.912	-11.281	-14.488	-16.775	-18.961	-19.833	-20.951	-21.228
40	-7.658	-4.776	-2.069	-2.219	-4.741	-7.343	-10.394	-13.133	-15.358	-16.584	-17.423	-17.876	-16.369
35	-2.373	-1.192	-0.466	-1.682	-2.678	-4.088	-6.040	-9.481	-11.224	-12.989	-11.868	-11.776	-11.115
30	0.697	1.520	0.360	-0.523	-0.618	-1.658	-3.097	-4.262	-6.668	-6.503	-7.550	-7.934	-7.737
25	3.514	3.619	2.630	0.805	0.070	0.457	-1.429	-1.695	-2.567	-2.935	-3.121	-2.864	-3.193
20	5.542	5.470	4.139	3.207	2.135	1.722	1.157	0.981	0.655	0.582	0.640	0.427	1.199
15	6.786	6.473	5.408	5.707	5.071	4.673	4.158	4.248	3.942	4.503	4.191	5.258	5.905
10	8.242	7.713	7.021	7.643	7.967	8.047	8.031	8.102	8.485	8.677	9.329	9.450	10.140
5	10.305	10.018	9.642	10.172	10.555	11.793	12.682	13.222	14.189	14.656	14.776	13.614	13.614
0	11.336	11.146	11.334	12.863	14.794	16.789	18.334	19.424	20.004	20.004	20.276	19.886	19.471
-5	11.897	11.806	12.321	17.414	14.431	21.634	22.757	23.032	23.401	23.637	23.808	22.591	22.641
-10	12.139	12.033	12.609	17.283	14.280	15.561	20.083	20.145	21.310	22.352	23.675	24.725	23.000
-15	12.181	12.038	11.917	12.231	12.682	13.427	16.059	14.958	14.718	17.409	15.129	16.988	18.564
-20	12.126	11.947	11.734	11.817	12.110	12.450	12.579	12.870	13.471	14.594	16.157	20.031	16.536
-25	12.034	11.854	11.637	11.199	11.263	12.033	13.067	16.230	13.330	15.395	19.273	17.923	14.254
-30	11.770	11.541	10.789	10.200	10.062	10.583	12.241	16.152	12.910	13.859	14.968	17.882	13.858
-35	11.341	11.081	10.694	10.007	5.503	9.180	9.951	15.013	12.642	12.779	13.172	13.624	14.414
-40	10.796	10.452	10.197	9.524	8.845	8.007	8.544	11.621	14.204	12.628	12.452	12.505	13.278
-45	9.375	9.342	9.337	8.709	7.920	7.523	7.188	9.052	9.949	12.332	11.013	11.558	11.644
-50	7.384	7.497	7.716	7.511	6.916	6.408	6.110	5.573	7.014	8.252	8.445	9.061	9.045
-55	1.136	1.052	5.124	5.501	5.075	4.498	3.984	4.013	4.924	5.209	5.111	5.239	5.516
-60	-2.005	-2.169	-1.204	3.356	3.330	2.621	1.879	1.373	1.339	1.134	0.999	0.894	0.965
-65	-5.258	-5.475	-5.250	0.038	0.122	0.339	-0.564	-1.196	-1.900	-2.614	-3.032	-3.201	-3.057
-70	-7.667	-8.072	-7.264	-3.379	-3.330	-3.640	-4.194	-4.749	-5.520	-6.074	-6.261	-6.383	-6.470
-75	-8.622	-9.045	-8.248	-6.273	-6.105	-6.381	-7.168	-8.005	-8.786	-9.784	-8.311	-8.302	-8.545
-80	-6.009	-6.315	-5.778	-8.565	-8.903	-9.310	-9.676	-10.185	-10.363	-9.784	-8.918	-8.936	-9.398
-85	-10.259	-10.490	-11.055	-11.752	-12.058	-11.519	-11.841	-12.014	-11.799	-11.206	-11.011	-10.895	-10.986
-90	-11.441	-11.515	-12.323	-12.528	-12.741	-13.035	-13.161	-13.509	-12.913	-11.673	-11.960	-11.930	-11.648
-95	-14.134	-13.842	-13.572	-13.415	-14.244	-14.169	-14.266	-14.273	-15.161	-14.542	-14.601	-13.528	-13.017
-100	-16.010	-15.743	-16.072	-15.761	-15.751	-15.179	-15.381	-15.911	-16.022	-16.607	-15.358	-14.054	-13.177
-105	-17.068	-17.541	-18.075	-18.071	-18.495	-17.503	-17.523	-17.270	-16.051	-15.310	-14.076	-13.154	-12.888
-110	-18.736	-18.523	-18.790	-18.296	-18.221	-18.340	-19.063	-17.535	-17.495	-17.413	-16.863	-15.706	-15.748
-115	-19.544	-19.429	-19.111	-17.705	-17.514	-17.157	-17.216	-17.244	-17.139	-16.764	-16.365	-16.163	-15.557
-120	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227	-15.227
AVE	1.552	2.134	2.264	2.752	2.687	2.592	2.564	2.585	2.200	2.251	2.205	2.401	1.927

MAP NG. = 10
TEMPERATURE (DEGREES CENTIGRADE)
MLM

EXP. 11 - HUTPAC 11 - MARCH 72 - PAND
S/P = 400.000 CONTIN = 5.000 GLOBAL MEAN = 0.27344E 00
120.0 SAMPLES

LAT	45E	50E	55E	60E	65E	70E	75E	80E	85E	90E	95E	100E	105E	110E	115E
90	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622	-45.622
86	-43.431	-43.431	-43.431	-43.431	-43.431	-43.431	-43.431	-43.431	-43.431	-43.431	-43.431	-43.431	-43.431	-43.431	-43.431
82	-39.225	-39.225	-39.225	-39.225	-39.225	-39.225	-39.225	-39.225	-39.225	-39.225	-39.225	-39.225	-39.225	-39.225	-39.225
78	-36.862	-36.862	-36.862	-36.862	-36.862	-36.862	-36.862	-36.862	-36.862	-36.862	-36.862	-36.862	-36.862	-36.862	-36.862
74	-33.265	-33.265	-33.265	-33.265	-33.265	-33.265	-33.265	-33.265	-33.265	-33.265	-33.265	-33.265	-33.265	-33.265	-33.265
70	-28.872	-28.872	-28.872	-28.872	-28.872	-28.872	-28.872	-28.872	-28.872	-28.872	-28.872	-28.872	-28.872	-28.872	-28.872
66	-24.845	-24.845	-24.845	-24.845	-24.845	-24.845	-24.845	-24.845	-24.845	-24.845	-24.845	-24.845	-24.845	-24.845	-24.845
62	-20.765	-20.765	-20.765	-20.765	-20.765	-20.765	-20.765	-20.765	-20.765	-20.765	-20.765	-20.765	-20.765	-20.765	-20.765
58	-16.570	-16.570	-16.570	-16.570	-16.570	-16.570	-16.570	-16.570	-16.570	-16.570	-16.570	-16.570	-16.570	-16.570	-16.570
54	-12.345	-12.345	-12.345	-12.345	-12.345	-12.345	-12.345	-12.345	-12.345	-12.345	-12.345	-12.345	-12.345	-12.345	-12.345
50	-8.117	-8.117	-8.117	-8.117	-8.117	-8.117	-8.117	-8.117	-8.117	-8.117	-8.117	-8.117	-8.117	-8.117	-8.117
46	-3.945	-3.945	-3.945	-3.945	-3.945	-3.945	-3.945	-3.945	-3.945	-3.945	-3.945	-3.945	-3.945	-3.945	-3.945
42	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229
38	6.433	6.433	6.433	6.433	6.433	6.433	6.433	6.433	6.433	6.433	6.433	6.433	6.433	6.433	6.433
34	12.609	12.609	12.609	12.609	12.609	12.609	12.609	12.609	12.609	12.609	12.609	12.609	12.609	12.609	12.609
30	18.785	18.785	18.785	18.785	18.785	18.785	18.785	18.785	18.785	18.785	18.785	18.785	18.785	18.785	18.785
26	24.961	24.961	24.961	24.961	24.961	24.961	24.961	24.961	24.961	24.961	24.961	24.961	24.961	24.961	24.961
22	31.137	31.137	31.137	31.137	31.137	31.137	31.137	31.137	31.137	31.137	31.137	31.137	31.137	31.137	31.137
18	37.313	37.313	37.313	37.313	37.313	37.313	37.313	37.313	37.313	37.313	37.313	37.313	37.313	37.313	37.313
14	43.489	43.489	43.489	43.489	43.489	43.489	43.489	43.489	43.489	43.489	43.489	43.489	43.489	43.489	43.489
10	49.665	49.665	49.665	49.665	49.665	49.665	49.665	49.665	49.665	49.665	49.665	49.665	49.665	49.665	49.665
6	55.841	55.841	55.841	55.841	55.841	55.841	55.841	55.841	55.841	55.841	55.841	55.841	55.841	55.841	55.841
2	62.017	62.017	62.017	62.017	62.017	62.017	62.017	62.017	62.017	62.017	62.017	62.017	62.017	62.017	62.017
-2	68.193	68.193	68.193	68.193	68.193	68.193	68.193	68.193	68.193	68.193	68.193	68.193	68.193	68.193	68.193
-6	74.369	74.369	74.369	74.369	74.369	74.369	74.369	74.369	74.369	74.369	74.369	74.369	74.369	74.369	74.369
-10	80.545	80.545	80.545	80.545	80.545	80.545	80.545	80.545	80.545	80.545	80.545	80.545	80.545	80.545	80.545
-14	86.721	86.721	86.721	86.721	86.721	86.721	86.721	86.721	86.721	86.721	86.721	86.721	86.721	86.721	86.721
-18	92.897	92.897	92.897	92.897	92.897	92.897	92.897	92.897	92.897	92.897	92.897	92.897	92.897	92.897	92.897
-22	99.073	99.073	99.073	99.073	99.073	99.073	99.073	99.073	99.073	99.073	99.073	99.073	99.073	99.073	99.073
-26	105.249	105.249	105.249	105.249	105.249	105.249	105.249	105.249	105.249	105.249	105.249	105.249	105.249	105.249	105.249
-30	111.425	111.425	111.425	111.425	111.425	111.425	111.425	111.425	111.425	111.425	111.425	111.425	111.425	111.425	111.425
-34	117.601	117.601	117.601	117.601	117.601	117.601	117.601	117.601	117.601	117.601	117.601	117.601	117.601	117.601	117.601
-38	123.777	123.777	123.777	123.777	123.777	123.777	123.777	123.777	123.777	123.777	123.777	123.777	123.777	123.777	123.777
-42	129.953	129.953	129.953	129.953	129.953	129.953	129.953	129.953	129.953	129.953	129.953	129.953	129.953	129.953	129.953
-46	136.129	136.129	136.129	136.129	136.129	136.129	136.129	136.129	136.129	136.129	136.129	136.129	136.129	136.129	136.129
-50	142.305	142.305	142.305	142.305	142.305	142.305	142.305	142.305	142.305	142.305	142.305	142.305	142.305	142.305	142.305
-54	148.481	148.481	148.481	148.481	148.481	148.481	148.481	148.481	148.481	148.481	148.481	148.481	148.481	148.481	148.481
-58	154.657	154.657	154.657	154.657	154.657	154.657	154.657	154.657	154.657	154.657	154.657	154.657	154.657	154.657	154.657
-62	160.833	160.833	160.833	160.833	160.833	160.833	160.833	160.833	160.833	160.833	160.833	160.833	160.833	160.833	160.833
-66	167.009	167.009	167.009	167.009	167.009	167.009	167.009	167.009	167.009	167.009	167.009	167.009	167.009	167.009	167.009
-70	173.185	173.185	173.185	173.185	173.185	173.185	173.185	173.185	173.185	173.185	173.185	173.185	173.185	173.185	173.185
-74	179.361	179.361	179.361	179.361	179.361	179.361	179.361	179.361	179.361	179.361	179.361	179.361	179.361	179.361	179.361
-78	185.537	185.537	185.537	185.537	185.537	185.537	185.537	185.537	185.537	185.537	185.537	185.537	185.537	185.537	185.537
-82	191.713	191.713	191.713	191.713	191.713	191.713	191.713	191.713	191.713	191.713	191.713	191.713	191.713	191.713	191.713
-86	197.889	197.889	197.889	197.889	197.889	197.889	197.889	197.889	197.889	197.889	197.889	197.889	197.889	197.889	197.889
-90	204.065	204.065	204.065	204.065	204.065	204.065	204.065	204.065	204.065	204.065	204.065	204.065	204.065	204.065	204.065
AVG	1.009	0.259	-0.395	-0.695	-0.948	-1.088	-1.045	-0.886	-1.043	-1.070	-0.776	-0.433	-0.222	-0.320	-0.270

[illegible]

APPENDIX C
CORRESPONDING MAP NUMBERS IN THE
OLD AND NEW VERSIONS OF MAPGEN

Appendix C

CORRESPONDING MAP NUMBERS IN THE OLD^a AND
NEW VERSIONS OF MAPGEN

New	Old	Old	New
1	5	1	2
2	1	2	5
3	27	3	6
4	6	4	10
5	2	5	1
6	3	6	4
7	10	7	--
8	24	8	27
9	23	9	15
10	4	10	7
11	25	11	12
12	11	12	13
13	12	13	16
14	26	14	18
15	9	15	20
16	13	16	--
17	--	17	--
18	14	18	--
19	--	19	26
20	15	20	25
21	22	21	--
22	Neg of 30	22	21
23	--	23	9
24	--	24	8
25	20	25	11
26	19	26	14
27	8	27	3
28	--	28	--
		29	--
		30	Neg of 22
		31	23

^a"Old" map numbers are those used in the
earlier documentation (Ref. 1).

APPENDIX D
PROGRAM VARIABLES AND SYMBOLS

Table D1

SYMBOLS USED IN MAPGEN MAIN ROUTINE

Name	Meaning
AVE	Contour interval for Map Display
AVR(46,72,40)	Accumulation arrays for current data set
CND	Flag for input contour intervals for Map Display
CONST	Value of weighting factor for this time point
DLN	Dashed-line isoline value for Map Display
EACH	No longer used
EXP	Flag for punched output, set to the integer NEXP
HEAD(19)	Run title
ID	Temporary storage for 4-character identification word
ISRC	Flag for M/A input data type--set to new disk format
KEYS(32)	Flags not used in MAPGEN
LEV	Flag, = true if SURF is a sigma level
LHLF	Flag used in some map routines; = true if SURF greater than 0.5
MAP(41)	Map numbers for current data set
NAME(13)	Temporary storage for map titles
NEXP	Integer value of EXP
NOOUT	Flag for COMP3; call = 0 if COMP3 not called for the time point
PRN	Print flag for Map Display
SNT(40)	Storage for variables no longer used in MAPGEN
SRF(40)	SURF values for current data set
SURF	The sigma level, pressure, or flag describing the map
TEND	Ending time of accumulation of data set
TICE	The melting point of ice (= 273.1 deg K)
TO	Starting time of accumulation of data set
WF(46,2)	Weighting functions for zonal means
WORK2(46,92)	The map values for the current time point
XID(40)	Storage for 4-character identification word for maps
XNAME(13,40)	Storage for map titles
XN(40)	Storage of weighting factors for accumulations
XSTAGI(40)	Flags for u or v grids in zonal direction
XSTAGJ(40)	Flags for u or v grids in meridional direction
XZM(46,40)	Accumulation of zonal means
XZMM(40)	Accumulation of global means
XZM2(46,40)	Accumulation of zonal means over oceans
ZM(46)	Temporary storage for zonal means
ZMM	Temporary storage for global mean
ZM2(46)	Temporary storage for zonal means over oceans
ZN	Value of weighting factor for current map accumulation

Table D2

THE LARGE MAPGEN ARRAYS

Name	Dimensions	Description, Use, and/or Map Reference	Also Called	Stored in
ACPPC1	(46,72)	Accumulated precipitation array--see User's Guide	---	MISC
ACPPC3	(46,72)	Accumulated precipitation array--see User's Guide	---	MISC
ACPPLS	(46,72)	Accumulated precipitation array--see User's Guide	---	MISC
ACRET0	(46,72)	Sum of RET0T arrays--see Map 28	---	DATA28
ACSC0S	(46,72)	Sum of SC0SZ arrays--see Map 28	---	DATA28
ALBED0	(46,72)	Surface albedo	ALS in C0MP3 and RET0T cal- culations	MISC
AVER	(46,72,40)	Sum of map data arrays	---	Local variable in MAIN
CC	(46,72,4)	Cloudiness: CL1, CL2, CL3, and CL--see Map 14	---	EXCOM
C0NM	(46,72)	Temporary storage for Map 7, not in any common	---	Local variable MAP 7 routine
C0NV	(46,72)	Packed S4 and T4--see Maps 9 and 21	SD	MISC
CPC1	(46,72)	Latent heating in layer 1, C1 + PC1--see Map 24	---	EXCOM
CPC3	(46,72)	Latent heating in layer 3, C3 + P3--see Map 24	---	EXCOM
FD	(46,72)	Temporary storage, Map 7 and C0MP3	{ PU H(46,72,2) TD	MISC
GT	(46,72)	Ground temperature, part of the state vector	---	QARY
GW	(46,72)	Ground wetness, part of state vector	---	QARY
H	(46,72,1)	Temporary storage for Map 7	{ PHI PV W	} MISC
	(46,72,2)	Temporary storage Map 7 and C0MP3	{ PU FD TD	
P	(46,72)	Surface pressure parameter, part of state vector	---	QARY
PHI	(46,72,1)	Temporary storage for Map 7	{ H(46,72,1) PV W	MISC
PRCLH	(46,72)	Latent heating in layers, PREC + CLH--see Map 24	---	EXCOM
PREGT	(46,72)	Pre-C0MP3 ground temperature	---	PRE3
PREGW	(46,72)	Pre-C0MP3 ground wetness	---	PRE3
PREQ3	(46,72)	Pre-C0MP3 level 3 mixing ratio	---	PRE3
PRET	(46,72,2)	Pre-C0MP3 levels 1 and 3 temperatures	---	PRE3

Table D2--continued

Name	Dimensions	Description, Use, and/or Map Reference	Also Called	Stored in
PT	(46,72)	Packed, H1 and H3, total heating--see Map 27	---	QTARY
PU	(46,72)	Temporary storage, Map 7 and COMP3	{ FD H(46,72,2) TD	MISC
PV	(46,72)	Temporary storage for Map 7	{ H(46,72,1) PHI W	MISC
Q3	(46,72)	Level 3 mixing ratio, part of state vector	---	QARY
Q3T	(46,72)	CICE, heat rising through ice--see Map 23	---	QTARY
RETOT	(46,72)	Total reflected solar radiation--see Map 28	---	EXCOM
SD	(46,72)	Packed S4 and T4--see Maps 9 and 21	CONV	MISC
SN	(46,72)	Packed R2 - R0, R4 - R2--see Map 26	VT(46,72,2)	QTARY
SSCOSZ	(46,72)	Solar radiation at top of atmosphere, SCOSZ--see Map 28	---	EXCOM
T	(46,72,2)	Levels 1 and 3 temperatures, part of state vector	---	QARY
TD	(46,72)	Temporary storage, Map 7 and COMP3	{ FD H(46,72,2) PU	MISC
TOPOG	(46,72)	Topography; temperature positive for ocean, less than 10 ⁻⁶ for land ice	---	MISC
TS	(46,72,2)	R4 net upward long-wave radiation at surface-- see Map 22	UT(46,72,2)	QTARY
TT	{ (46,72,1)	Packed AS1, AS3, solar absorption in layers-- see Map 25	---	} QTARY
	{ (46,72,2)	Packed F4, E4, evaporation and sensible heat-- see Maps 18-20	---	
U	(46,72,2)	Zonal winds for levels 1 and 3, part of state vector	---	QARY
UT	{ (46,72,1)	Temporary storage in AVRX	WORK1	} QTARY
	{ (46,72,2)	R4 net upward long-wave radiation at surface-- see Map 22	TS	
V	(46,72,2)	Meridional winds for levels 1 and 3, part of state vector	---	QARY
VT	{ (46,72,1)	Temporary storage in map subroutines	WORK2	} QTARY
	{ (46,72,2)	Packed R2 - R0, R4 - R2--see Map 26	SN	
W	(46,72)	Temporary storage for Map 7	{ H(46,72,1) PHI PV	MISC
WORK1	(46,72)	Temporary storage in AVRX	UT(46,72,1)	QTARY
WORK2	(46,72)	Temporary storage in map subroutines	VT(46,72,1)	QTARY

Table D3

MAP DISPLAY VARIABLES IN MAIN ROUTINE

Name	Description
AVE	Input contour interval, SINT set to it
AVO	Dashed-line value, set from DLN
CN	Current contour interval, initialized at the lowest contour value
CN2	The smallest grid value
CN3	The largest grid value
CONFLG	Flag for drawing the contour map
CONIN(15)	The input contour values, if any
CONINT(3)	BCD information - 'ISOLINES AT'
CONO	Input, real number of contour intervals; zero if none
CX(1500)	x-axis coordinates of lines forming the continental outlines--each set of two points defining a line
CY(1500)	y-axis coordinates of lines forming the continental outlines--each set of two points defining a line
DLAT	Number of degrees per grid point on y-axis
DLN	Input dashed-line value, AVO set to it
DLON	Number of degrees per grid point on x-axis
DT	Used in an older version of Map Display; should be input as zero in this version. At one time, MAPGEN did not accumulate the arrays, but put each array on tape (one for each map every 6 hours, for usual case). Map Display then accumulated the arrays. The option was deleted, but some of the logic still exists in Map Display.
DTT	Small time increment used in time comparisons
DX	Number of rasters corresponding to one grid interval on the x-axis in the contour map
DY	Number of rasters corresponding to one grid interval on the y-axis in the contour map
EACH	Not used; should be input as zero
EXPN	Not used
FLAG7	Logical flag for the meridional mass flux profile map done in map 7
FREQ	Not used, but either this or EACH should be input as zero. Input along with TA in columns 41-50
IC	Number of points in CX, CY array. IC/2 lines drawn
IM	Integer number of grid points on x-axis, set to XMAX
JM	Integer number of grid points on y-axis, set to YMAX
LAT(47)	Latitude grid points in degrees, used in POLP
LIN(3)	Used in CONTUR to speed up the isoline drawing in IGS. In COMMON/SPEED/
MAP	Map number read from cards

Table D3--continued

Name	Description
MAPNO	Map number read from tape
NAME7	The BCD name for the meridional mass flux profile map title
NOPR	Integer number of times to print, set from PRNO
NOR	Integer flag for projection type; set from ZNOR
PI	= 3.1415963, used in the conversion of radians and degrees
POI(2)	No longer used
PRNO	Input, real number of times to print the map data
RAD	= 6.375×10^6 meters, the radius of the earth
REW	Rewind flag to stop tape from being rewound twice while searching for a map's data record
SINT	Contour interval, set from AVE
SINTM	100 times SINT, the contour interval; used to prevent drawing of more than 100 contour intervals
SRF	SURF value read from card
SURF	SURF value read from tape
TA, TD	Starting time of map description, in days
TB, TE	Ending time of map description, in days
TC	A large time, set to 100 days beyond TB
TEND	End time read from tape, in hours
TOT	Total number of grid points, floating point, $XMAX * YMAX$
T0	Start time read from tape, in hours
T1	Start time read from tape, in days
T2	End time read from tape, in days
WF(46,2)	Weighting functions used for the global means; (J,1) for the π -grid; (J,2) for the u,v grid
WORK1(46,72)	Input continental outline data
WORK2(46,72)	Large array input from tape, equivalenced to WRK
WRK(46,72)	Large array input from tape, equivalenced to WORK2
XMAX	Number of grid points on x-axis, floating point
X1	Start of the plotting surface on the x-axis
Y1	Start of the plotting surface on the y-axis
ZMM	Global mean, recalculated from tape value
ZM(46)	Zonal means for large array, recalculated
ZM2(46)	Zonal means of the oceans from tape
ZM3(46)	Array for the meridional mass flux values calculated in map 7
ZNOR	Input real flag for type of projection for contour flag; NOR, its integer value, is used
ZNT(3)	BCD information - 'INTERVAL='
ZOPL	Flag for drawing the zonal means map

Table D4

ZONAL PROFILE PROGRAM VARIABLES

Name	Description
ACCZON(46,128)	Storage for time accumulation of profiles
CONSTS	In ACCVAL, the current weighting factor for the map data added to ACCZON
CONV(30)	Conversion factors for the input zonal arrays
FLGMAP	Flag indicating that a map is to be plotted, in EXEQ
ICARD(20)	Used to read the control cards
IPRO(129)	Profile type number for maps
ITITLE	Title for maps
NAMCOD(129)	Four-character identification for each map
NAMTYP(9)	Array containing the control words
NCODE	Default value for NAMCOD. Normally blank
NMAP	Number of profile maps input--counter
NPTZON	Number of zonal divisions, nominally 46
NTYPES	Number of different control words
NUM(129)	Number of accumulations in ACCZON array
NUMUNT	Unit number of input zonal means
NUMMAP	Number of types of profile maps
NUMZON	Number of input zonal means
SCALE(2,32)	Range for profile type in map area
SUMWT	The weighting factor for the array ACCZON, in EXEQ
T(3,129)	Start time, end time, and time range per profile (input in days, changed to hours)
TAU	In EXEQ, time of disk data sets in hours
TAULST	Time of last accumulated map data
TIMDIF	Time increment of data sets on disk
TIMMAX	Maximum time demanded in profile descriptions
TIMMIN	Minimum time demanded in profile descriptions
TISTD	Default value for start time. Nominally 0.1
T2STD	Default value for end time. Nominally 0.1
T3STD	Default value for time range. Nominally 0.4
WT(46)	Weighting function used in calculating zonal means
Z(200)	Mode set array for graphics programs

Table D5

SUBROUTINE MAPZON VARIABLES

Name	Description
DEL	Number of rasters from ZPT for the latitude labels
DELTA	Number of rasters to move label if two columns of numbers are printed
DIFFG	Number of rasters in the plotting surface in the x direction
EDG	Length of the lines bracketing the plotting surface
FLGINT	Flag, = true if the accumulation is more than one time point
FLGMIN	Flag, = true if two columns of numbers are printed in the profile map (the langley/minutes column)
GRIDX1	Left-hand x-axis value of the plotting surface
GRIDX2	Right-hand x-axis value of the plotting surface
GRIDY1	Lower y-axis value of the plotting surface
GRIDY2	Upper y-axis value of the plotting surface
IDUM	Dummy variable used in call to LINSEG
IMAP	Profile map number to plot
INØ(3)	BCD information, 'NO. MEAN ='
ISØ(3)	BCD information, 'SO. MEAN ='
IZØN(3)	BCD information, 'ZONAL MEANS'
MAPNO	Profile type number
NTIT(17)	Title for profile type
PLATP	Latitude counter in loop
SCALE1	Values at the left edge of the plotting surface
SCALE2	Values at the right edge of the plotting surface
SUMWT	Weighting factor for ACCZON
TAU	Last time point accumulated for this profile
T1	Start time of accumulation for this profile
T2	End time of accumulation for this profile
VAL	Raster point along the x-axis to print latitude labels
VALGBL	The global mean for the profile values
VALNØ	Northern hemisphere's zonal mean
VALSØ	Southern hemisphere's zonal mean
X1,Y1	Starting point of zonal mean line within plotting surface
X2,Y2	End point of zonal mean line within plotting surface
YLN1, to 5	Raster values of the y-axis for lines 1 (top line) to 5 of the headings
YPT	Raster value of y-axis in drawing graph
ZPT	Raster value of zero in the x-axis in the plotting surface
Z2ARY(46)	Zonal mean values in units of ly/min, if used

REFERENCES

1. Gates, W. L., E. S. Batten, A. B. Kahle, and A. B. Nelson, *A Documentation of the Mintz-Arakawa Two-Level Atmospheric General Circulation Model*, The Rand Corporation, R-877-ARPA, December 1971.
2. Brown, G. D., *IGS--The Integrated Graphics System for the S-C 4060*, The Rand Corporation, P-3722, November 1967.